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SOME ASPECTS AND RECENT RESULTS OF ELECTROMAGNETIC EFFECTS OF THUNDERSTORMS.

BY

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PART II.

THE VARIATION OF THE MAGNETIC FIELD AS CAUSED BY LIGHTNING DISCHARGES.

THE OBSERVATION METHOD.

An analysis of the variation structure of the main and multiple lightning discharges when using the above mentioned method of measuring the field force will always be connected with experimental difficulties and lead to results of a limited value. The method used in earlier investigations (5) resulted (see Fig. 21) mainly in a statement of the variation of the maximal field force changes with the distance from the lightning paths, when adjacent strokes were considered.

The main and multiple strokes in a lightning discharge comprise the prevailing current variations, which are transporting the predominant charges along the lightning paths. It is near at hand to try to use the other field vector—the magnetic—when starting an analysis of the variation structure of the main and partial discharges. In view of all the possibilities offered by the cathode ray oscillographs it would hence be plausible to apply a purely electromagnetic method. The magnetic field variations caused by a lightning discharge could be observed by a system of frame aerials combined with amplifiers and cathode ray oscillographs. Such a system would permit a sweeping of lightning discharges over an extensive region and under undisturbed field conditions. With certain assumptions it will be possible to calculate the current intensity and variations with sufficient accuracy and more in detail than with other methods.

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We have been operating with such methods at the Institute of High Tension Research first during the years 1933–1936. The results have been published in two papers (8, 9). Either the methods or the results were without objections—we are in these measurements, as will be seen by the following, dealing with many experimental difficulties. During the years 1937–1939 extensive experiments were carried out to improve the methods, and during the thunderstorm seasons of 1940 and 1941 we were able to obtain rather extended results.

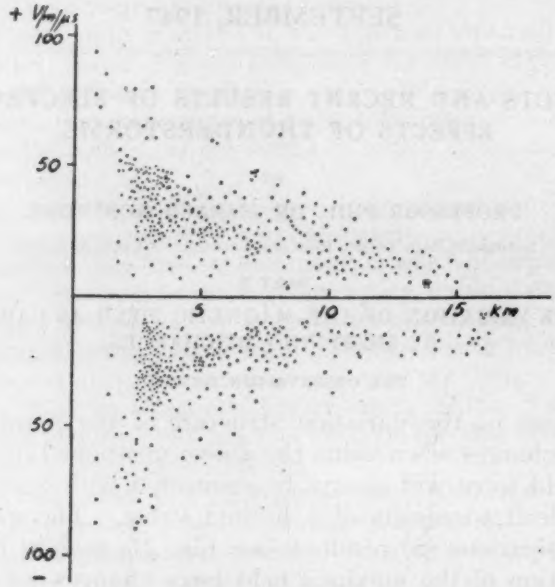

FIG. 21. Maximal field changes from lightning discharges in relation to the distance of the lightning channel.

PRINCIPLE OF MEASUREMENTS AND EXPERIMENTAL ARRANGEMENTS.

The method consists of using a frame aerial in connection with an amplifier and a cathode ray oscillograph. The path of the recorded lightning was measured by two operators, who observed the angular height and the angular direction. The daylight during the thunderstorms prevented photographic recording. The distance was measured by the time difference between lightning flash and clap of thunder.

SHIELDED FRAME AERIALS.

The most difficult problem was to construct a frame aerial with pure frame characteristics and without any distortion from the electric field variations. The frame was provided with a metallic shield. In order to diminish disturbing charging currents of the shield we divided the

shield of the frame in 14 electrically separated sections in a star-shaped connection to earth (see Fig. 22). If the shield was not divided up as described, we found by oscillographic records that an impulse of the form A, Fig. 23, was transformed to the form B. An external electro-

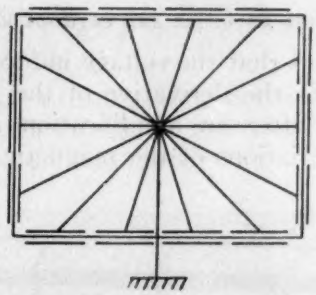

FIG. 22. Divided shield arrangement of frame aerial.

static shield was necessary and the final used frame arrangement is shown in Fig. 24. The dimensions of the frames were 3 × 4 m., and they consisted of two turns of 1 mm. copper wire. The reason for using only two turns was to eliminate the influence of proper oscillations of the frame, which had such a high proper frequency that they passed the amplifier without disturbance effects.

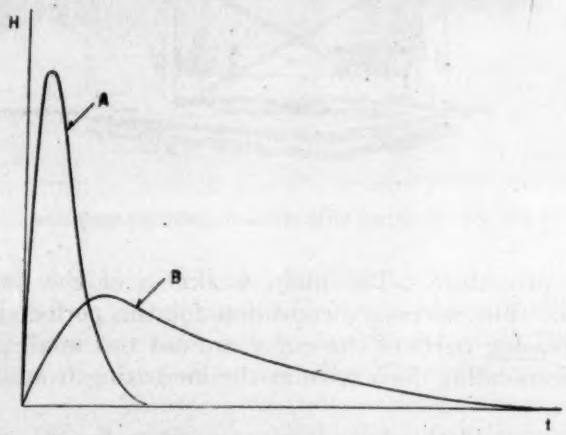

FIG. 23. Transformation of an impulse passing a shield arrangement.

A special controlling arrangement was introduced in order to detect disturbances from the electric field vector. Two cathode ray oscillographs were simultaneously recording alternatively connected to one half of each term of the frame. The records from the two oscillographs were in a very good agreement and hence the influence of the electric field

on one half of the frame would be added to the record from the lightning discharge, on the other half turn the corresponding disturbance would have quite the opposite effect. A round-about device was, as is seen by Fig. 24, introduced in order to direct the frame quickly against the center of a lightning storm.

INTEGRATION CIRCUIT AMPLIFIER AND CATHODE RAY OSCILLOGRAPHS.

The method involves that the voltage induced in the frame aerial is directly proportional to the derivative of the magnetic field and the oscillograms recorded after an amplification must be integrated in order to obtain the variations of the magnetic field. This is in itself

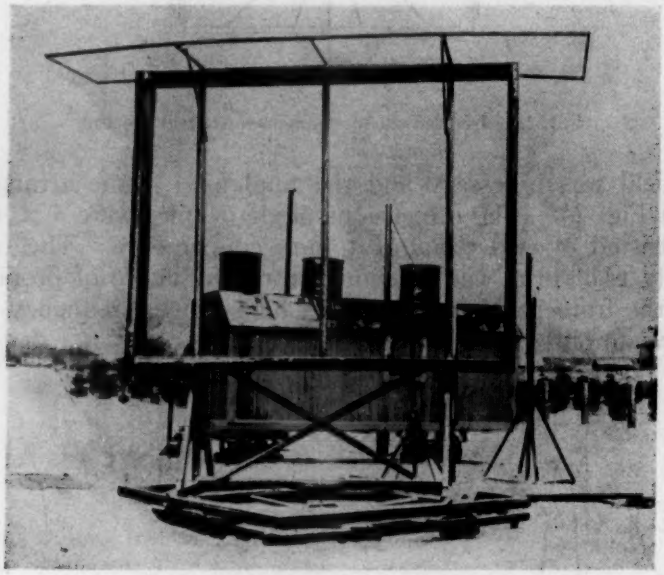

FIG. 24. External view of frame aerial arrangement.

an elaborate procedure. The main weakness of the method lies on another level. The necessary condition for the perfect integration is that the decreasing parts of the curve are not too small in comparison with the corresponding derivative in the increasing frontal parts of the curve.

In order to avoid this inconvenience and to be able to record also the slow-moving parts of the impulses as well, a special integration circuit method has been introduced. A diagram of the circuit is reproduced in Fig. 25. With the frame angle φ, the magnetic field force H and a turn aera of A cm.^{2} will be induced a voltage E calculated from the relation:

$$E = A \cdot dH\varphi/dt \cdot 10^{-8} \text{ (volt)}. \qquad (2)$$

If we consider in the circuit $R \gg 1/pC$ a current $I = E/R$ will be provoked, which charges the condenser C to the voltage V and thus:

$$V = \frac{1}{C}\int_0^t Idt = \frac{1}{RC}\int_0^t Edt = \frac{10^{-8}}{RC}\int_0^t A \cdot \frac{dH\varphi}{dt}\,dt$$

$$= \frac{A \cdot 10^{-8}}{RC}\int_0^H dH\varphi = \frac{A \cdot 10^{-8}}{R \cdot C} \cdot H\varphi \text{ (volt)}. \tag{3}$$

The condition for a correct integration is that $R \gg 1/pC$, i.e. that the applied voltage above the condenser must be very small in comparison with the voltage above the resistance.

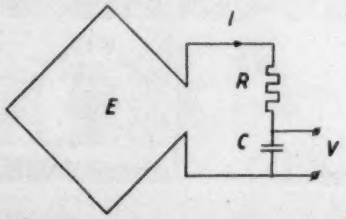

FIG. 25. Diagram of integration circuit.

The few turns of the frame aerial necessitated a high amplification of the voltage variations before recording in the oscillograph. To some extent the induced voltage was decreased by the integration circuit. A necessary condition must be that the amplifiers were aperiodic and able to operate without distortion on a wide frequency band. A specially constructed amplifier using triodes in a resistance coupling was introduced. By the use of only 6 times amplification in each of the six steps and a parallel push-pull in the output step it was possible to gain an amplification of about 50,000 times. It was possible to fix the higher frequency limit to about 200 kilocycles and the lower one to some ten periods per second. The aperiodic amplifier set is reproduced in Fig. 26.

To record the integrated and amplified voltage variations from the frame we used the cathode ray oscillographs of the author's (10) special pattern that has also been briefly described in this JOURNAL (3). A special method was used when recording the variations of the magnetic field by the frame. We operated three oscillographs simultaneously on the same amplifier and frame aerial. One was operating on a slow-moving time axis and the two others on a rapid one. One of the rapid operating was recording and the other one was destined for visual observations and control of the exposure situation. The slow-moving records were used in order to be able to detect the sequence with regard to time of individual consecutive current pulses as recorded by the rapid operated time axis.

MECHANISM OF LIGHTNING DISCHARGES.

The methods of calculating the current variation of a lightning by the aid of the corresponding variations of the magnetic fields are very complicated. The problem is intimately associated with the general discharge mechanism of a lightning. We have found it necessary to

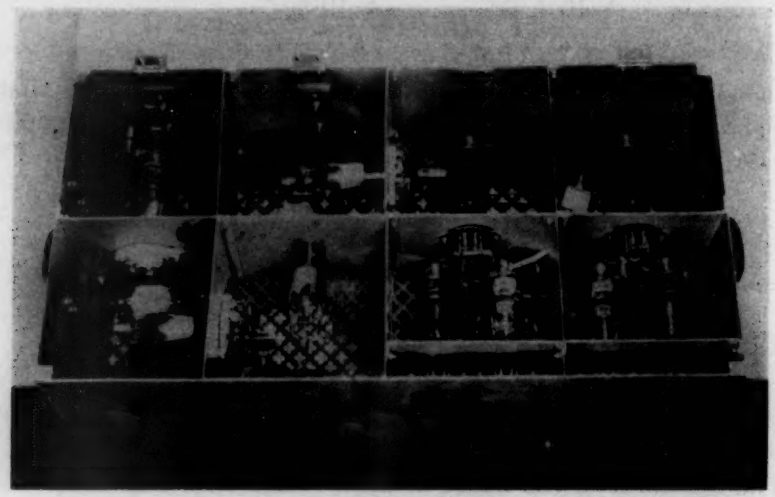

FIG. 26. Aperiodic amplifier set.

discuss this mechanism more in detail with consideration to the development of a typical vertical lightning so more as we have limited our oscillographic measurements and calculations to vertical lightning paths.

The thunderstorm cloud of Fig. 27 is supposed to have a region of negative charge of such an intensity that an ionization column is de-

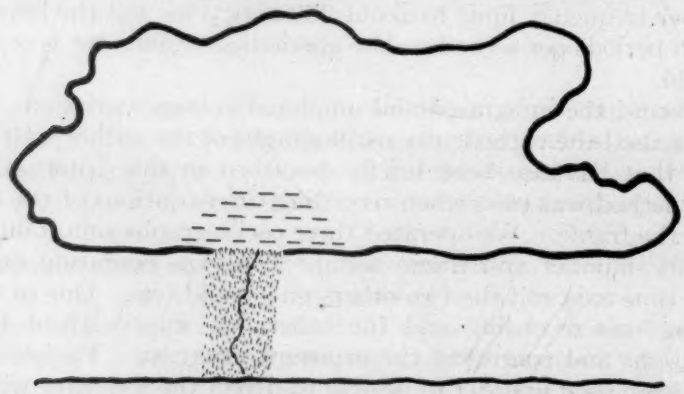

FIG. 27. Ionization column with penetrating streamer from intense negative charge region of a thunderstorm cloud.

veloped, in which the pre-discharge streamers are successively penetrating against the earth's surface. When the streamers have reached a contact between cloud and earth, a return stroke starts upwards with an initial velocity that in the vicinity of the earth may be supposed to be so high as the order of 200 m./μsec. The initial velocity will diminish after some microseconds of penetration and the decrease of the velocity will be marked by a corresponding diminishing of the front steepness of the current with time—e.g. with the penetration of the current up to higher regions in the cloud. The result will be a first steep front in the

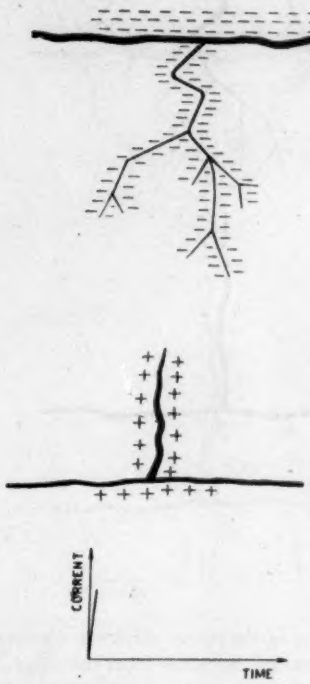

FIG. 28. Initial stage of the return stroke in a lighting discharge.

current curve as is explained by Fig. 28. The steepness is diminishing with time. The return stroke is still penetrating farther up in the cloud, where the regions of the charges of opposite sign are accumulated. A mutual neutralization of charges will result in beginning variations up and down in the current curve as illustrated by Fig. 29. When the stage is reached as in Fig. 30 the current path is already closed and the current fluctuations will be more prominent. When the current is fully developed, it will be quite acceptable to assume the current to be the same along the whole current path. In other words we may consider the current state as a quasi-stationary one.

In the cases of multiple strokes in the same channel the first discharge procedure will be repeated and the penetration periods and intervals between subsequent strokes are bound up with several important factors and especially with the field intensity within such regions of the thunderstorm clouds that are mainly active in the discharge procedure. The sequence of multiple strokes will be discussed further on.

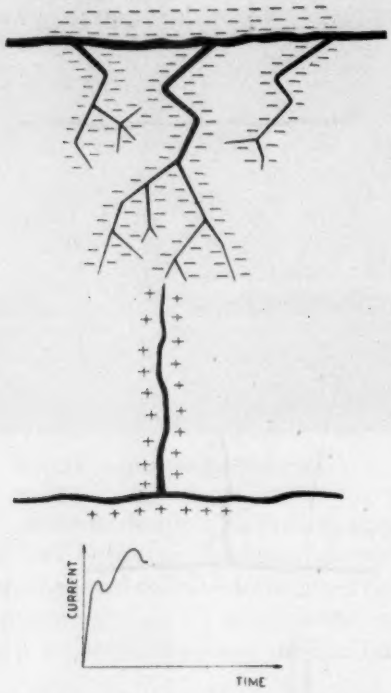

FIG. 29. Penetration of the return stroke to connection stage with descending branches from the cloud.

METHODS FOR CALCULATION OF LIGHTNING CURRENTS.

The most rational way to deal with the calculation of the lightning currents should be to base them upon a group of observed values of the magnetic field variations and thus the magnetic moments. They must be located and simultaneously recorded at chosen distances from the lightning path. Such distance values at for instance 2, 4 and 6 kilometers should without doubt constitute a possibility for a rational solution of the current calculation problem. The method must afford extensive experimental arrangements and simultaneous operation of observation stations and instruments in a prodigious scale, which must be an undertaking of the future.

If we assume that a lightning discharge at each moment has the same current value along the whole channel, we can consider the current as closed in a circuit between the earth and the cloud. This scheme assumes that the current has been developed simultaneously along the total length of the path—an approximation of the current conditions that must be opposed against what we have considered before and thus against a purely physical interpretation of the discharge procedure. On the other hand the approximated conditions lead to very plain calculations that have another interesting feature. As will be seen

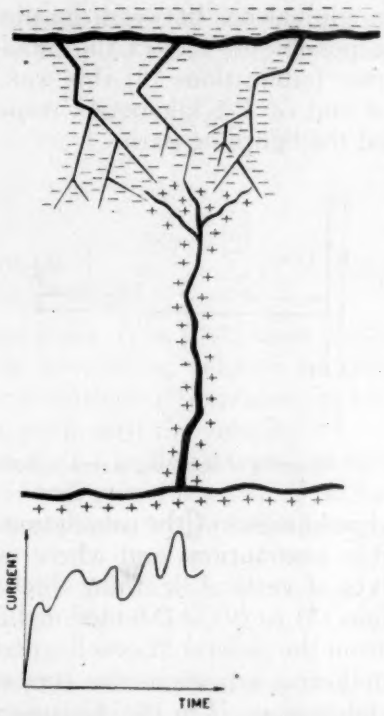

FIG. 30. Stage of full connection between return stroke and branches from the cloud.

further on the method leads to results, which coincide from a purely formal point of view astonishingly well with results from calculation methods, where as far as possible the physical conditions have been taken into consideration. This coincidence is an accidental one, which, with some precautions, can be used as a first approximation in calculation of the current variation values.

When the point of observation is situated close to the lightning path, the travelling time of the field changes will be small in comparison to the front time of the current. This will allow us to omit the radia-

tion field with reference to Fig. 31, where the height of the vertical lightning is h, its distance from the observation point P is r, both expressed in kilometers, we obtain from the Biot-Savarts law the current I_1 in kiloamperes, or kA when H is the magnetic field force in 10^{-3} Gauss:

$$I_1 = \frac{r \cdot H}{2} \cdot \frac{\sqrt{r^2 + H^2}}{h}. \tag{4}$$

The division with 2 is necessary on account of the reflection at the earth surface and is introduced under the consideration of a homogeneous conductivity as a mean value in all directions from the lightning path. From this follows an equivalence between the direct and the reflected field. It will not be possible to neglect the radiation term at greater distances and in earlier publications (8) this was considered by using only distances of 2–4 and of 2–5 kilometers respectively between the observation point and the lightning path.

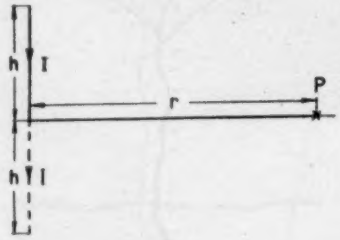

FIG. 31. Diagram of lightning current calculation.

A more detailed development of the calculation methods under some different and plausible assumptions and where we have started from the H variation curves of vertical lightning discharges has resulted in the following equations (5) to (9). Detailed deductions of these equations when starting from the general Maxwell equations are given in the paper (1). In the following equations the current I is given in kiloamperes, r and h in kilometers, H in 10^{-3} Gauss and t in microseconds. If we take the influence of the radiation term into consideration, the following expression (5) for the current I_2 is obtained:

$$I_2 = \frac{c^2 r}{2h} \cdot \int_0^t e^{\frac{c(\tau - t)}{r}} H(\tau) d\tau,$$

$$I_2 = \frac{0.15 r}{h} \int_0^t e^{\frac{0.3(\tau - t)}{r}} H(\tau) d\tau. \tag{5}$$

The formula is valid for greater distances and when the lightning path has been substituted by an arc of a circle with its middle in the observation point. At small distances it will be a too far-going approximation.

In the two formulas above no consideration has been taken to the transient velocity, with which the current is expanding along the channel. If this velocity is taken in account of, we must consider the lightning discharge as a charge emerging from the striking point of the earth. In the most simple case the charge is supposed to move upwards with v km./μsec. along the channel penetrated by the streamers. The charge is assumed to have the same time distribution along all parts of the lightning channel. The transported charges are assumed to be immediately neutralized when reaching the upper end of the lightning path. In reality it will take time for the neutralization especially as the cloud charge has a widespread distribution in space.

Under the above assumptions and considering r to be constant along the path, the following formula for I_3 may be deduced:

$$I_3 = 0.15r \int_0^t \frac{1}{v} e^{\frac{0.3(\tau - t)}{r}} \sum_{\nu=0}^{\left[\frac{t}{t_1}\right]} H'(\tau - \nu t_1) d\tau,$$

$$I_3 = 0.15r \int_0^t \frac{1}{v} e^{\frac{0.3(\tau - t)}{r}} \sum_{\nu=0}^{\left[\frac{t}{t_1}\right]} H'(\tau - \nu t_1) d\tau, \qquad (6)$$

As before I is expressed in kA, H in 10^{-3} Gauss, t in μsec., r in kilometers. Further v signifies the proceeding velocity in kilometers/μsec. in the following numerical calculations 100 m/μsec. and t_1 the time necessary to cover the lightning path with the velocity v.

In the summation $[t/t_1]$ is the integral part of the number t/t_1. As the recorded curves will give values for H, it may be convenient to transform the expression to one with partial integration.

$$I_3 = 1.5r \sum_{\nu=0}^{\left[\frac{t}{t_1}\right]} H(t - \nu t_1) - 0.45 \cdot \int_0^t e^{\frac{0.3(\tau - t)}{r}} \sum_{\nu=0}^{\left[\frac{t}{t_1}\right]} H(\tau - \nu t_1) d\tau. \qquad (7)$$

There are two different well-marked stages in the lightning current procedure. The first stage covers the proper front time reckoned from the beginning of the current starting from the earth to the time, when the front is fully developed and a closed current is maintained between the cloud and the ground. The second stage covers the time period when the current is fully developed, varying up and down and finally decreasing. It will in this stage be a first acceptable approximation to consider the current to be a quasi-stationary one.

During the first stage or t_1 seconds it will be possible to use the formula for $I(t)$:

$$I(t) = 0.15r \int_0^t \frac{1}{v} e^{\frac{0.3(\tau - t)}{r}} H'(\tau) d\tau; \; 0 < t < t_1. \qquad (8)$$

When $t \geq t_1$, we obtain:

$$I(t) = I(t_1) \cdot e^{\frac{0.3(\tau - h)}{\tau}} + \frac{0.15\tau}{h} \int_h^t e^{\frac{0.3(\tau - t)}{\tau}} H(\tau) d\tau. \quad (9)$$

Current values calculated by using the relations of equations (8) and (9) and are in the following marked with I_4.

SOME TYPICAL CALCULATED CURVES.

In order to check the methods of calculations by the equations given above we have calculated some typical H curves recorded from different distances of the lightning paths. The results of the calculations are reproduced in Figs. 32–39. For each case we reproduce the

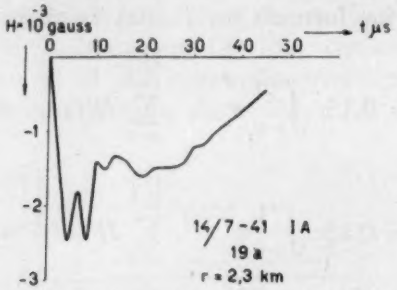

FIG. 32. Variation curve of the magnetic field.

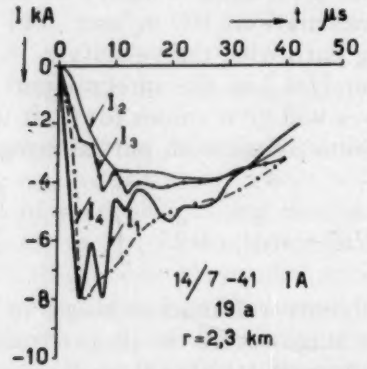

FIG. 33. Calculated current variation curves corresponding to the magnetic field of Fig. 32.

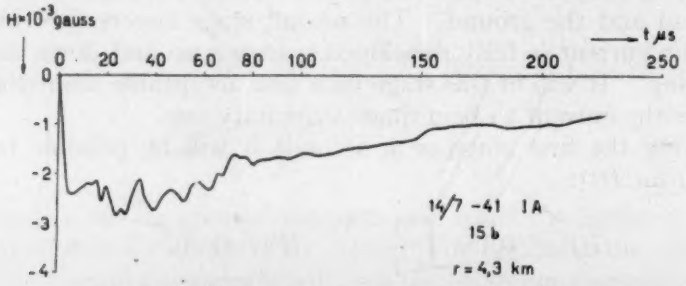

FIG. 34. Variation curve of the magnetic field.

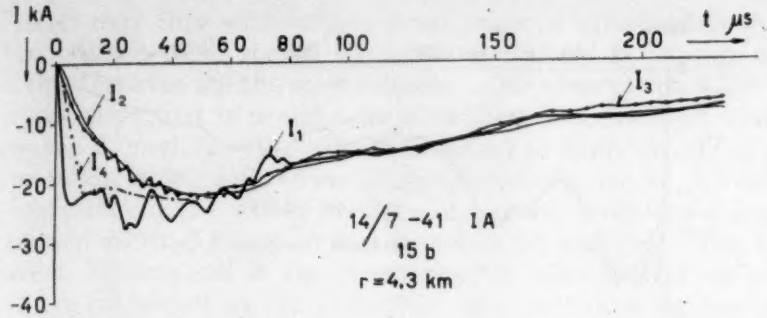

FIG. 35. Calculated current variation curves corresponding to the magnetic field of Fig. 34.

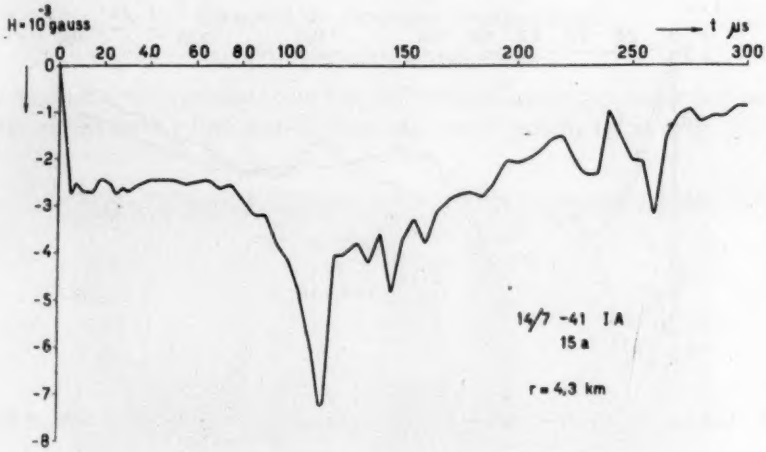

FIG. 36. Variation curve of the magnetic field.

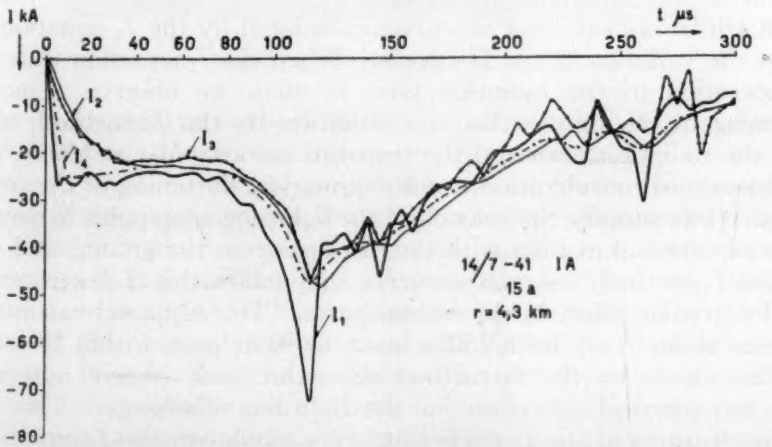

FIG. 37. Calculated current variation curves corresponding to the magnetic field of Fig. 36.

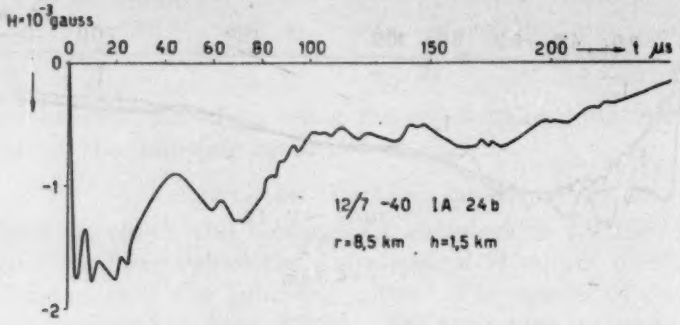

FIG. 38. Variation curve of the magnetic field.

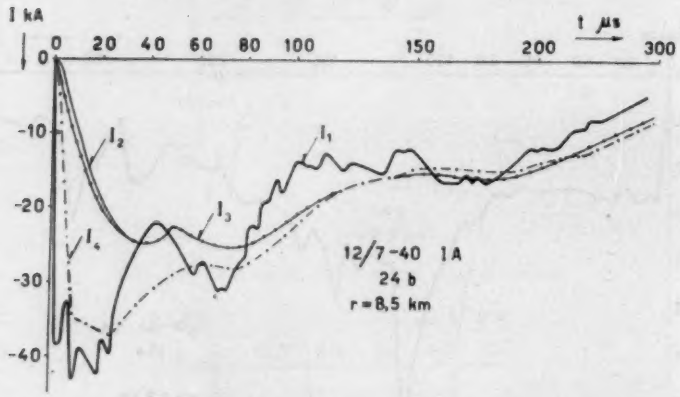

FIG. 39. Calculated current variation curves corresponding to the magnetic field of Fig. 38.

original H curve, from which the calculation has started. The arrows in the calculated current curves indicate the equation, which has been used at the corresponding calculations.

It will be obvious that all curves calculated by the I_1 equation will follow the variation of the H curves. When the I_2 equation thus with consideration to the radiation term is used, we observe a marked flattening of the front. Also a calculation by the I_3 method, where both the radiation term and the transient velocity of $v = 100$ m/µsec. are taken into consideration, results in marked flattening of the frontal parts. If we suppose the velocity of the lightning's top point to decrease in an exponential manner with the distance from the ground and if we use the I_4 method, we receive curves that follow the H curves with a small flattening effect in the frontal parts. The supposed exponential decrease should vary from 250 m/µsec. to 50 m/µsec. within 10 µsec.

The curves by the I_4 method show the most evident agreement with the physical procedure in the lightning discharge. The front sloping features in the I_4 curves are very similar to the I_1 curves and

the latter may thus without any great error be substituted for the I_4 curves. When more special circumstances afford a detailed calculation, the I_4 curves are the most reliable. Our observation material has such extension that it would take a too long procedure of calculation to use the I_4 method. We have been forced to apply simplified graphical methods, which will not introduce appreciable errors. To calculate the maximal current values we have, e.g., used a combined graphical calculation method based on the equations (4) and (7). The current values in kiloamperes in the representative following curves of Figs. 47–58 are calculated by the I_1 method, but the values are not used in the following statistical representations. These are based on the above mentioned combined graphical method.

EXAMPLES OF RECORDED OSCILLOGRAMS.

Time Sequence of Multiple Strokes.

Original oscillograms from the lightning discharges recorded with the frame aerial and a low speed time axis are reproduced in Fig. 40. The

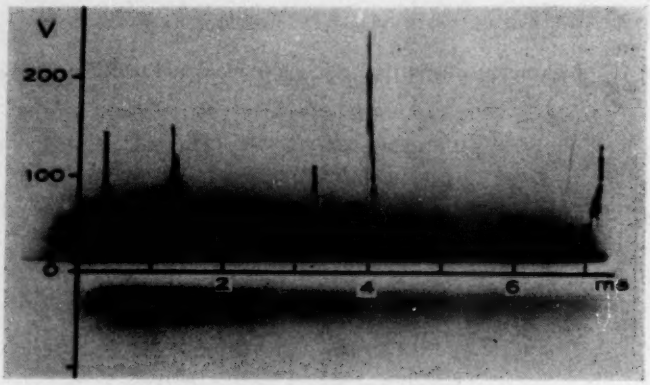

FIG. 40. Original oscillogram with slow-moving time axis.

fronts are marked as vertical lines. The records can, as already mentioned, be used to locate the time sequence of records with a rapid time variation. Such records were applied earlier on for another interesting analysis of the time sequence of multiple strokes. During the season of 1939 a large number of special tests were carried out at the Institute with cathode ray oscillographs. A number of 125 visible lightning strokes were recorded with the slow-moving method. The variation form and direction of the paths of the flashes were observed and sketched. The frame aerial was placed in such a position to give the maximal dH/dt value of the magnetic field. A collection of representative records is reproduced in Figs. 41–42, where the crest values of

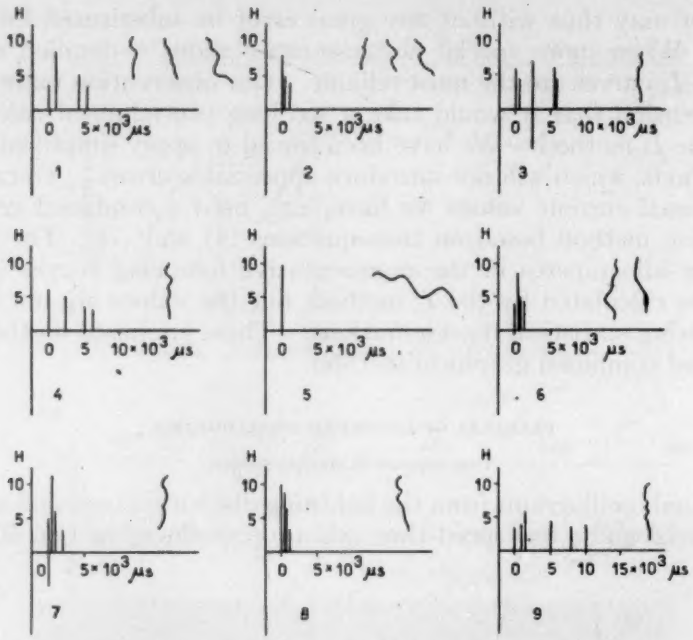

FIG. 41. Lightning paths in their relation to main and multiple strokes.

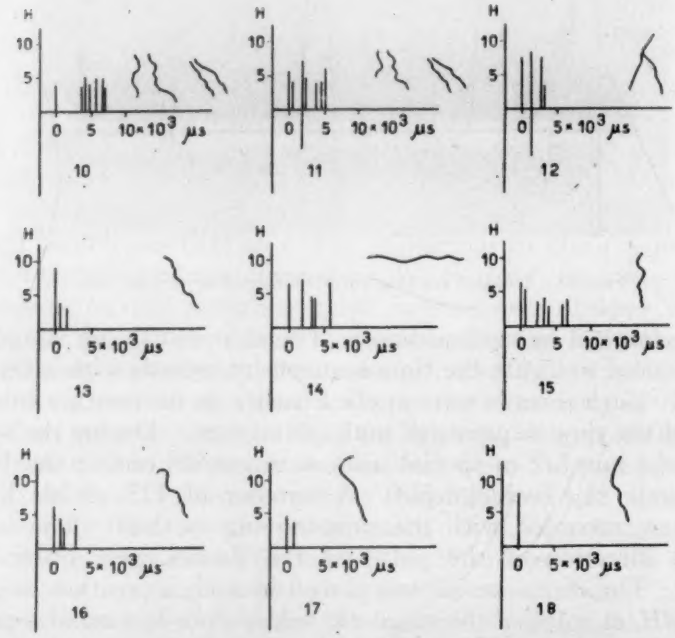

FIG. 42. Lightning paths in their relation to main and multiple strokes.

dH/dt are given an arbitrary scale. The observed lightning stroke forms are reproduced in the figures.

An examination of the observations does not result in any appreciable difference with regard to time sequence, when horizontal lightning paths are compared with more or less vertical ones. The mutual difference in the field intensity of multiple flashes was analyzed by 125 lightning flashes containing multiple strokes. The result is graphically

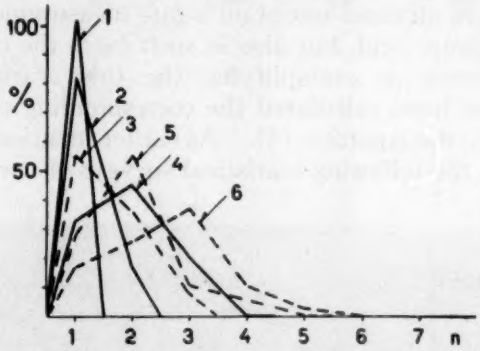

FIG. 43. Field intensities in relation to consecutive strokes.

reproduced in Fig. 43, where a lighting flash with only one discharge is given an intensity of 100 per cent. and so forth. In a lighting flash with two strokes the first occurring one will have the highest field intensity in 83 per cent. and with three in 56 per cent. The percentage distribution of the number of 125 strokes are given in Fig. 44, from

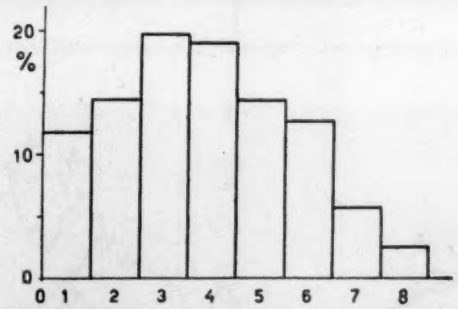

FIG. 44. Percentage distribution of 125 multiple strokes.

which follows that the mainly occurring number in multiple strokes was 3–4.

TYPICAL RAPID TIME VARIATION OSCILLOGRAMS.

Some typical original oscillograms, which represent voltage variations from vertical lightning discharges in frame aerial, are reproduced

in Figs. 45–46. An identification of the maximal amplitudes from simultaneously recorded oscillograms with a slow-moving time basis has allowed an investigation of curves from multiple discharges also in cases when the curves have been rather complicated. It is the first time when we have been able to record a considerable number of oscillograms from vertical lightning strokes and in Figs. 47–58 some typical ones are reproduced. A curve marked, e.g., with 3a, 3b and 3c means that the discharge has contained three multiple strokes in the given order. It was not possible in all cases to obtain a safe measurement of the variations of the magnetic field, but also in such cases the curves may offer considerable interest as exemplifying the time variation structure. When possible we have calculated the corresponding current values in kiloamperes using the equation (4). As earlier mentioned, these values were not used in the following statistical surveys of current values.

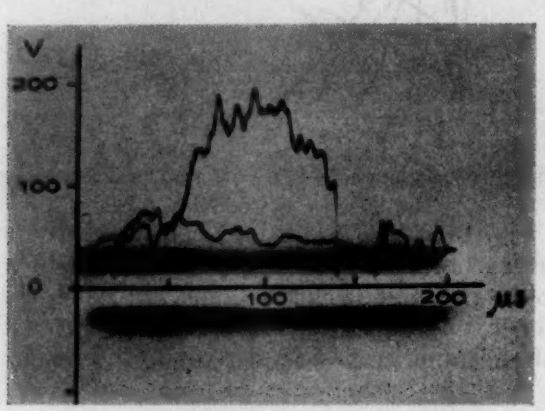

FIG. 45. Original oscillograms of lightning discharges with high speed time basis.

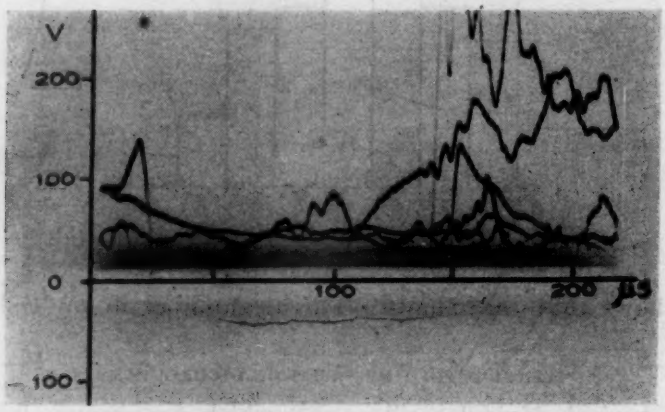

FIG. 46. Original oscillograms of lightning discharges with high speed time basis.

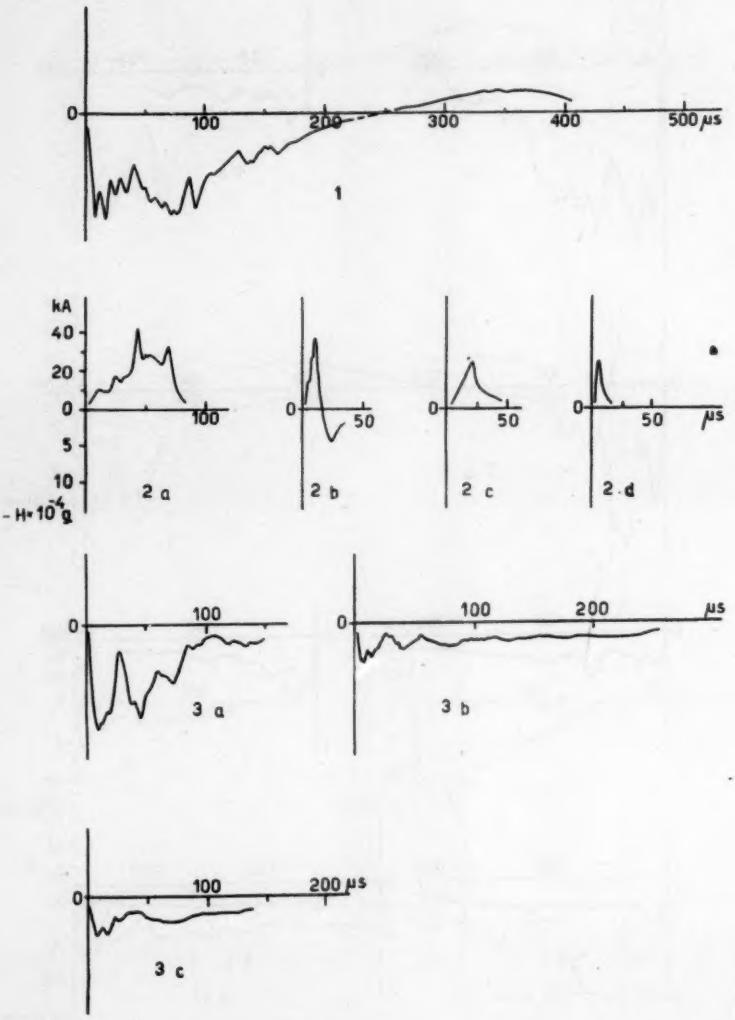
0
100
200
300
400
500 μs
1
kA
40
20
0
5
10
- H · 10⁻⁴ g
100
2 a
50
2 b
50
2 c
50
μs
2 d
100
3 a
100
200
μs
3 b
100
200 μs
3 c

FIG. 47.

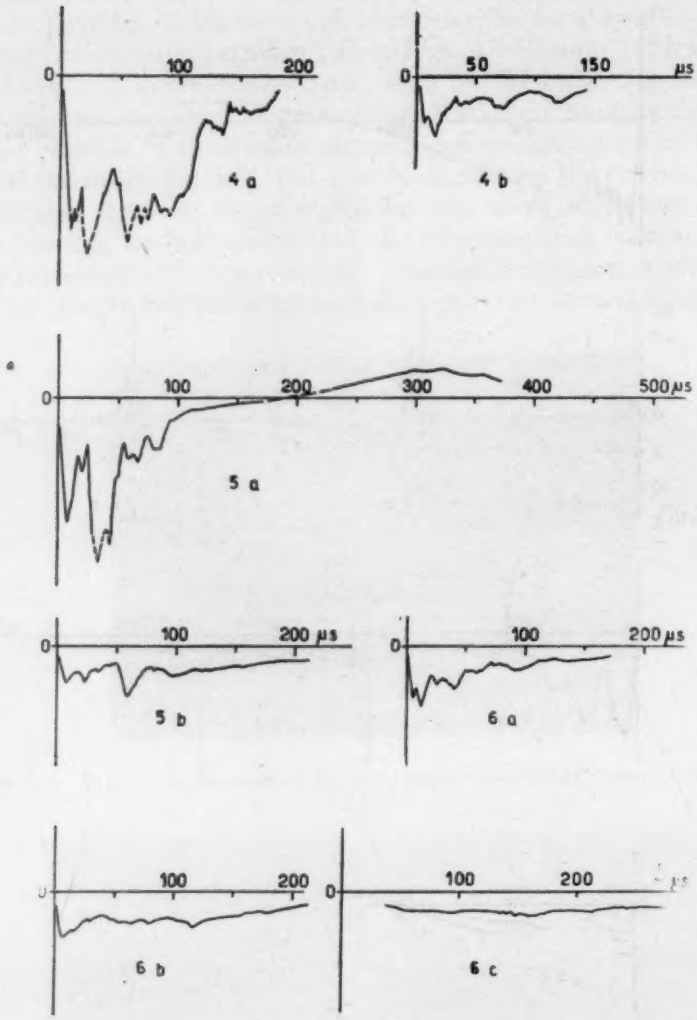
0
100
200
4 a
0
50
150
µs
4 b
0
100
200
300
400
500 µs
5 a
0
100
200 µs
5 b
0
100
200 µs
6 a
0
100
200
6 b
0
100
200
6 c

FIG. 48.

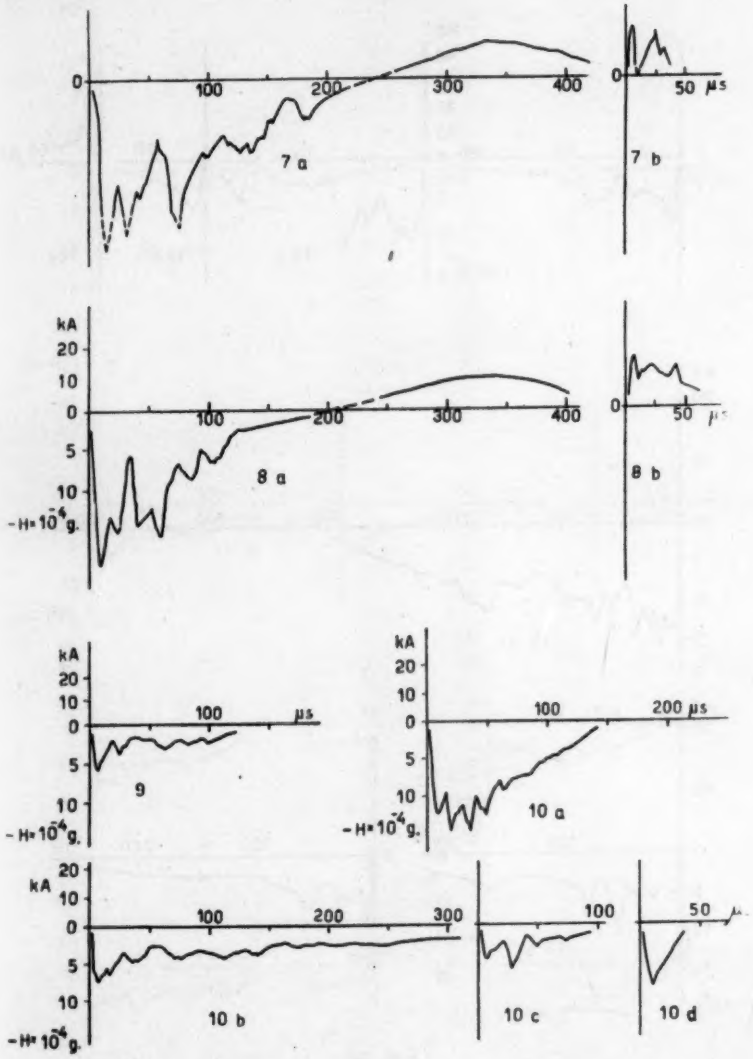
0
100
200
300
400
7 a
0
50 μs
7 b
kA
20
10
0
5
10
-H=10⁻⁴g.
8 a
8 b
9
100 μs
10 a
200 μs
10 b
10 c
10 d

FIG. 49.

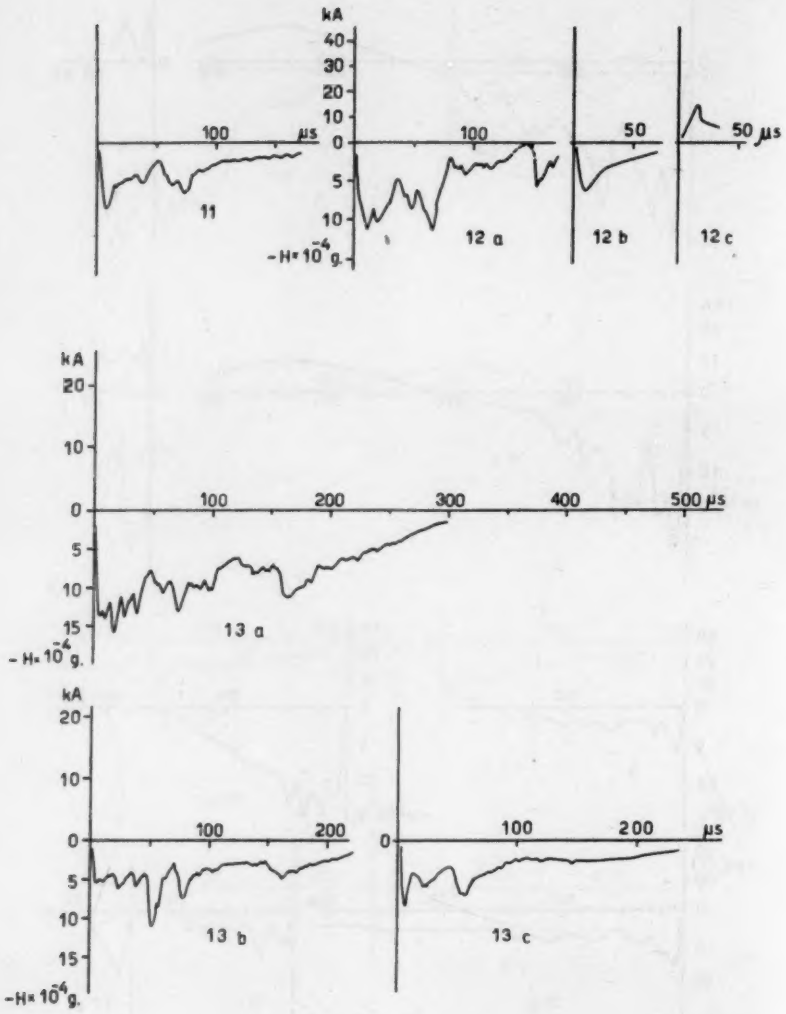
kA
40
30
20
10
0
5
10
100
µs
100
50
50 µs
11
12 a
12 b
12 c
-H×10⁻⁴g.
kA
20
10
0
100
200
300
400
500 µs
5
10
15
13 a
-H×10⁻⁴g.
kA
20
10
0
100
200
0
100
200
µs
5
10
15
13 b
13 c
-H×10⁻⁴g.

FIG. 50.

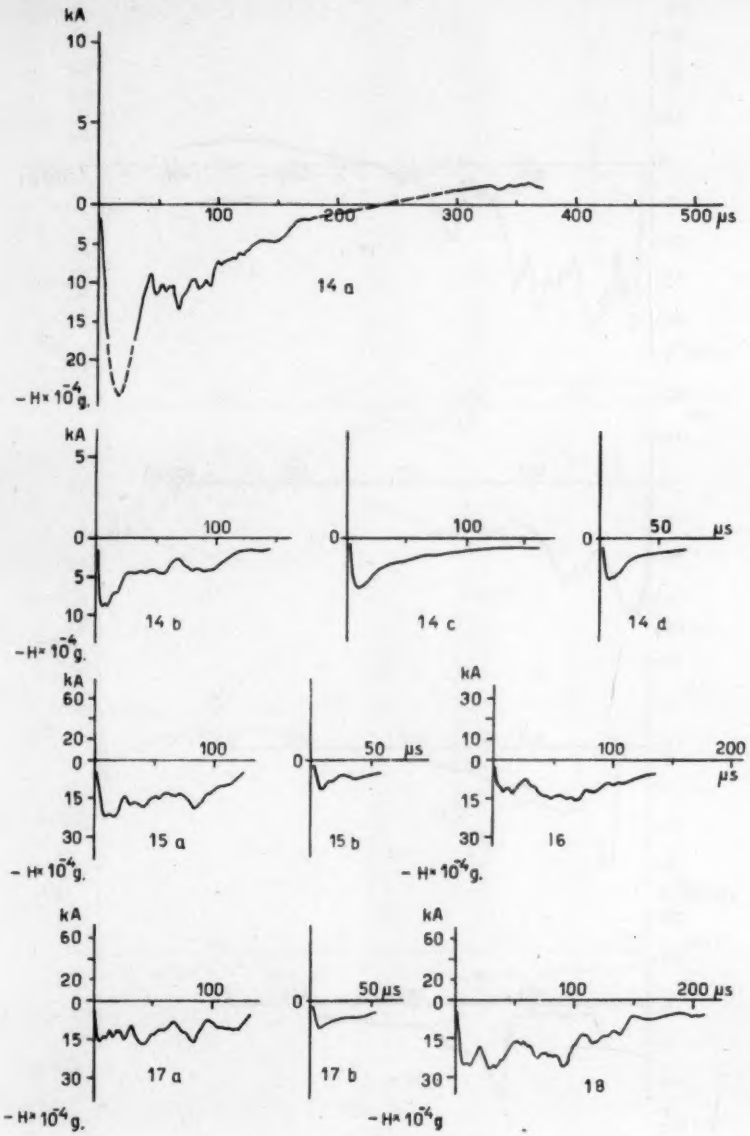
kA
10
5
0
100
200
300
400
500 μs
5
10
15
20
14 a
– H × 10⁻⁴ g.
kA
5
0
100
5
10
14 b
– H × 10⁻⁴ g.
0
100
14 c
0
50 μs
14 d
kA
60
20
0
100
15
30
15 a
– H × 10⁻⁴ g.
0
50 μs
15 b
kA
30
10
0
100
200
μs
15
30
16
– H × 10⁻⁴ g.
kA
60
20
0
100
15
30
17 a
– H × 10⁻⁴ g.
0
50 μs
17 b
kA
60
20
0
100
200 μs
15
30
18
– H × 10⁻⁴ g

FIG. 51.

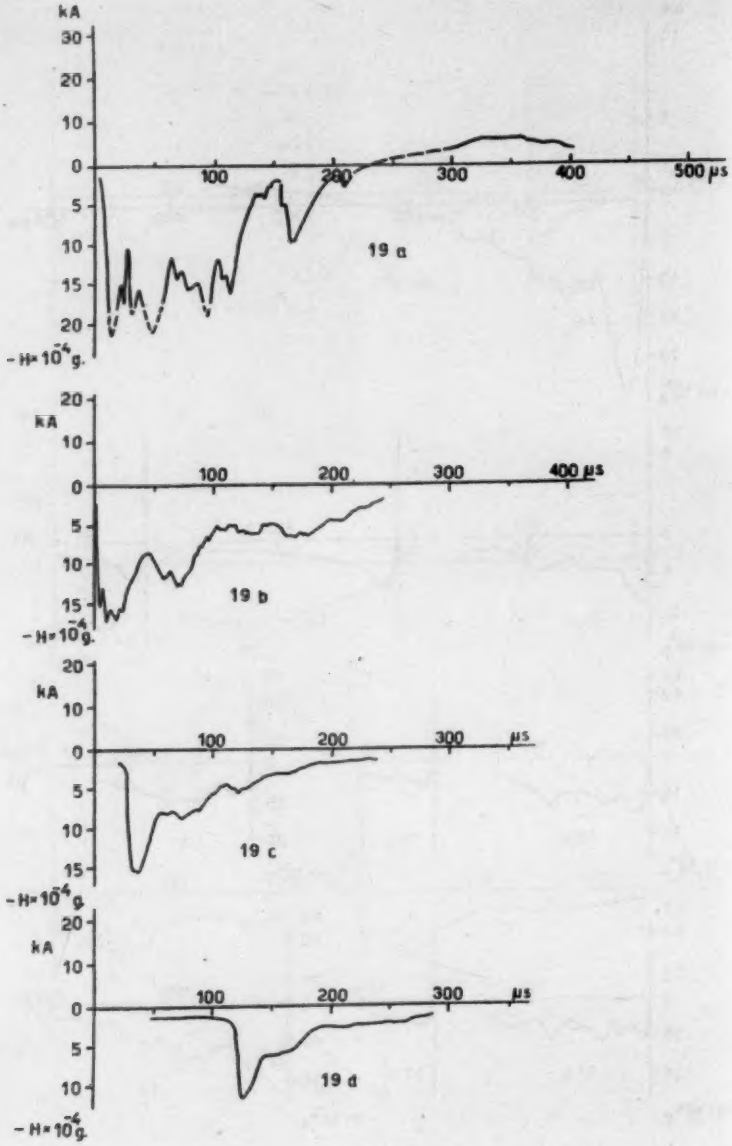
kA
30
20
10
0
5
10
15
20
100
200
300
400
500 µs
19 a
-H=10⁻⁴g.
kA
20
10
0
5
10
15
100
200
300
400 µs
19 b
-H=10⁻⁴g.
kA
20
10
0
5
10
15
100
200
300
µs
19 c
-H=10⁻⁴g.
kA
20
10
0
5
10
100
200
300
µs
19 d
-H=10⁻⁴g.

FIG. 52.

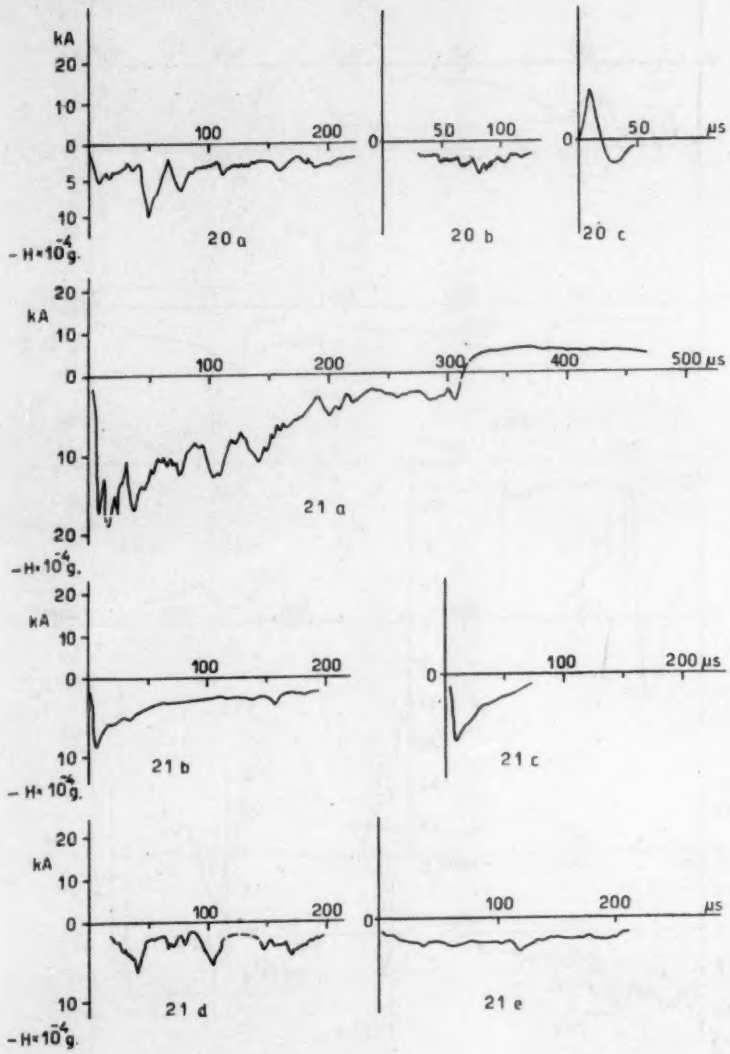
kA
20
10
0
5
10
100
200
20 a
– H×10⁻⁴g.
0
50
100
20 b
50
μs
20 c
kA
20
10
0
100
200
300
400
500 μs
10
20
21 a
– H×10⁻⁴g.
kA
20
10
0
100
200
10
21 b
– H×10⁻⁴g.
0
100
200 μs
21 c
kA
20
10
0
100
200
10
21 d
– H×10⁻⁴g.
0
100
200
μs
21 e

FIG. 53.

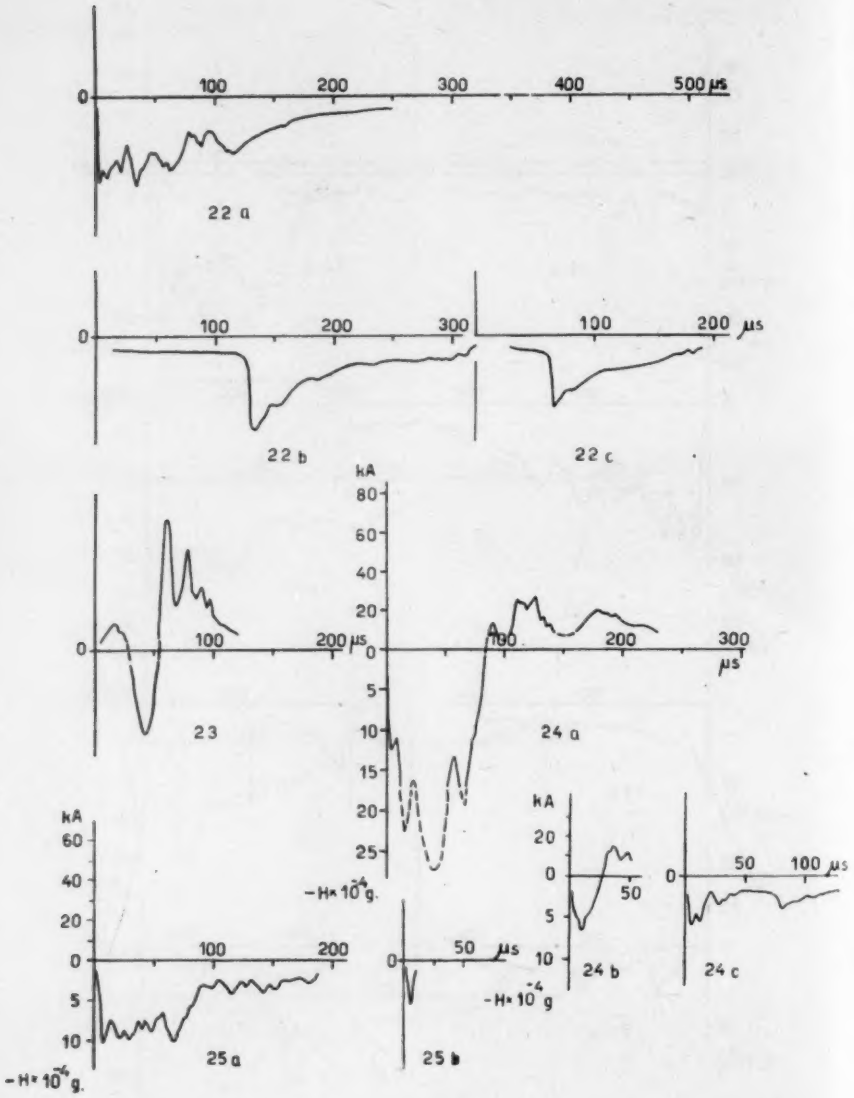
0
100
200
300
400
500 µs
22 a
100
200
300
100
200 µs
22 b
22 c
kA
80
60
40
20
0
100
200 µs
23
0
100
200
300
µs
5
10
15
20
25
24 a
-H× 10⁻⁴g.
kA
60
40
20
0
100
200
5
10
25 a
-H× 10⁻⁴g.
0
50 µs
25 b
kA
20
0
50
5
10
24 b
-H× 10⁻⁴g
0
50
100 µs
24 c

FIG. 54.

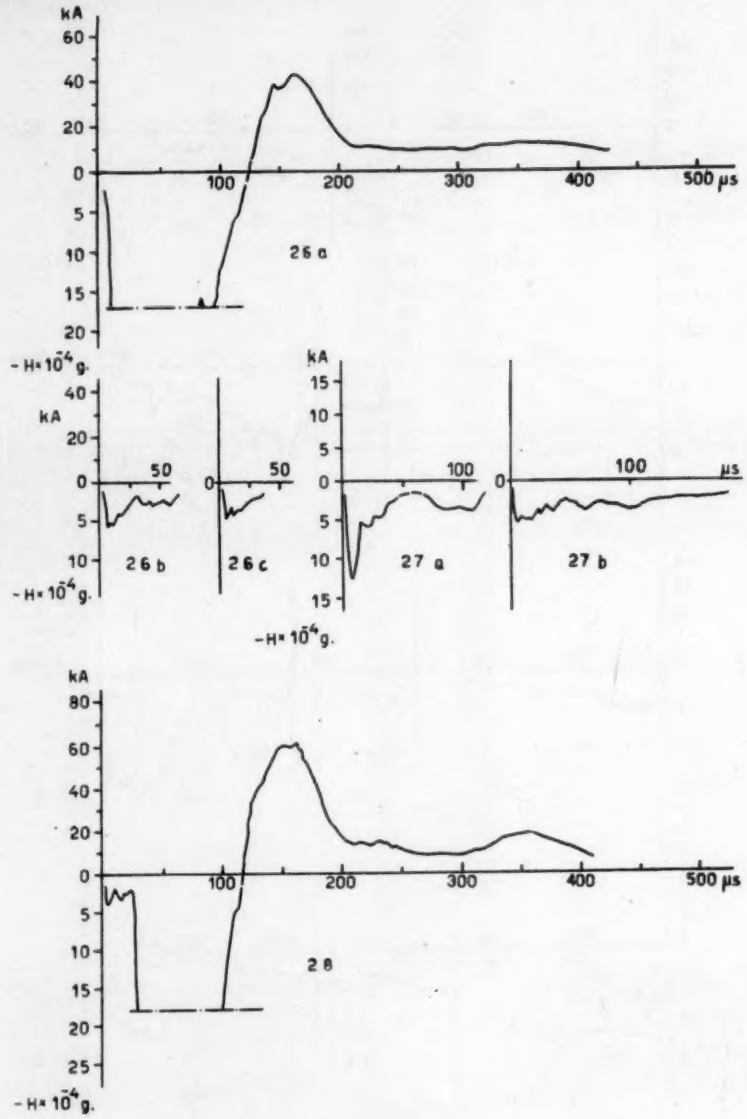
kA
60
40
20
0
100
200
300
400
500 μs
5
10
15
20
26 a
- H × 10⁻⁴ g.
kA
40
20
0
50
50
5
10
26 b
26 c
- H × 10⁻⁴ g.
kA
15
10
5
0
100
100
μs
5
10
15
27 a
27 b
- H × 10⁻⁴ g.
kA
80
60
40
20
0
100
200
300
400
500 μs
5
10
15
20
25
28
- H × 10⁻⁴ g.

FIG. 55.

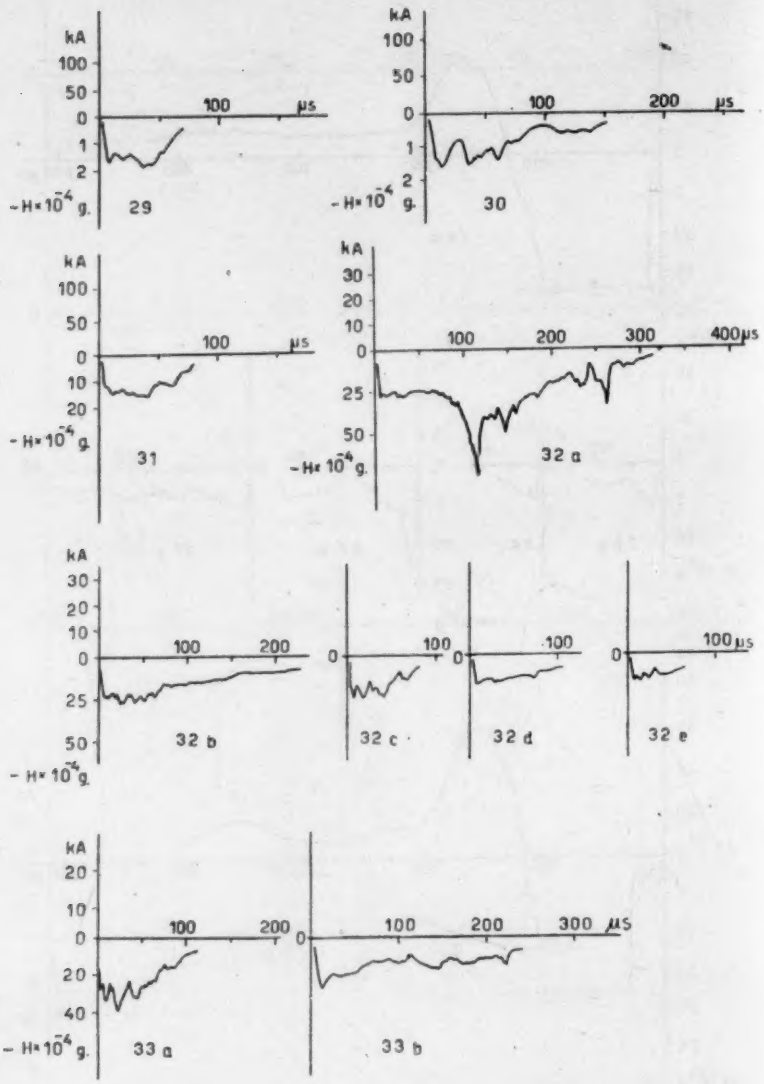
kA
100
50
0
1
2
100
µs
-H×10⁻⁴ g.
29
kA
100
50
0
1
2
100
200
µs
-H×10⁻⁴ g.
30
kA
100
50
0
10
20
100
µs
-H×10⁻⁴ g.
31
kA
30
20
10
0
25
50
100
200
300
400µs
-H×10⁻⁴ g.
32 a
kA
30
20
10
0
25
50
100
200
-H×10⁻⁴ g.
32 b
0
100
32 c
0
100
32 d
0
100µs
32 e
kA
20
10
0
20
40
100
200
-H×10⁻⁴ g.
33 a
0
100
200
300 µs
33 b

FIG. 56.

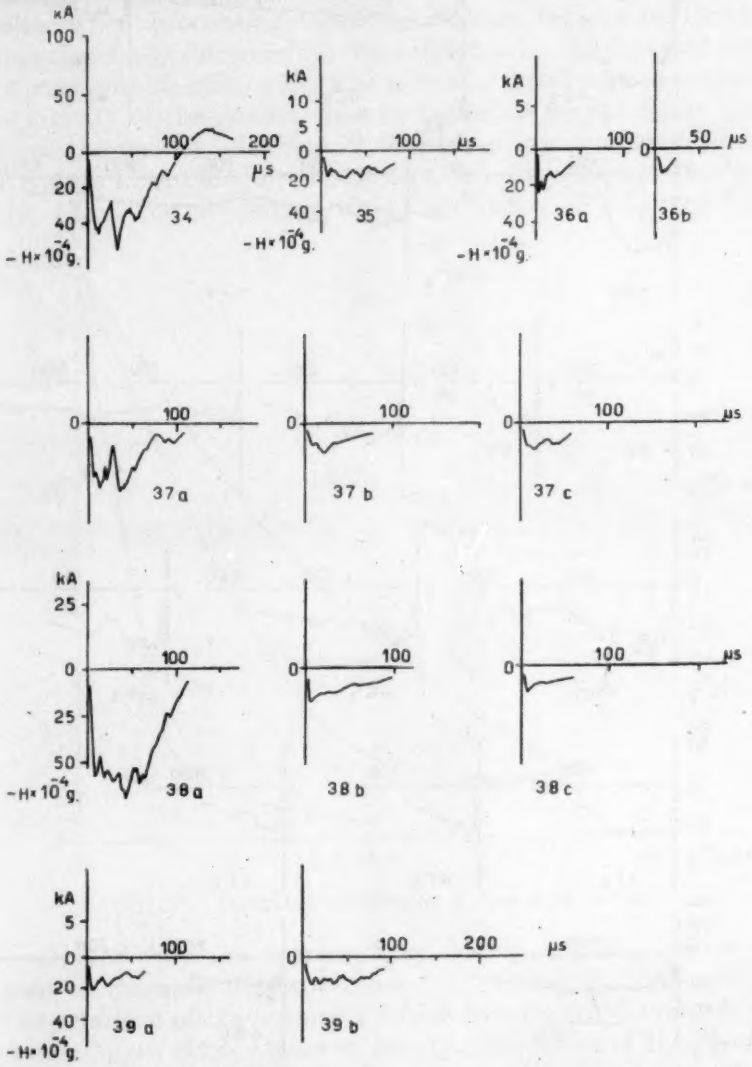
kA
100
50
0
20
40
100
200
μs
34
$-H\times10^{-4}$g.
kA
10
5
0
20
40
100
μs
35
$-H\times10^{-4}$g.
kA
5
0
20
40
100
0
50
μs
36a
36b
$-H\times10^{-4}$g.
0
100
37a
37b
37c
μs
kA
25
0
25
50
38a
38b
38c
$-H\times10^{-4}$g.
kA
5
0
20
40
100
39a
$-H\times10^{-4}$g.
0
100
200
μs
39b

FIG. 57.

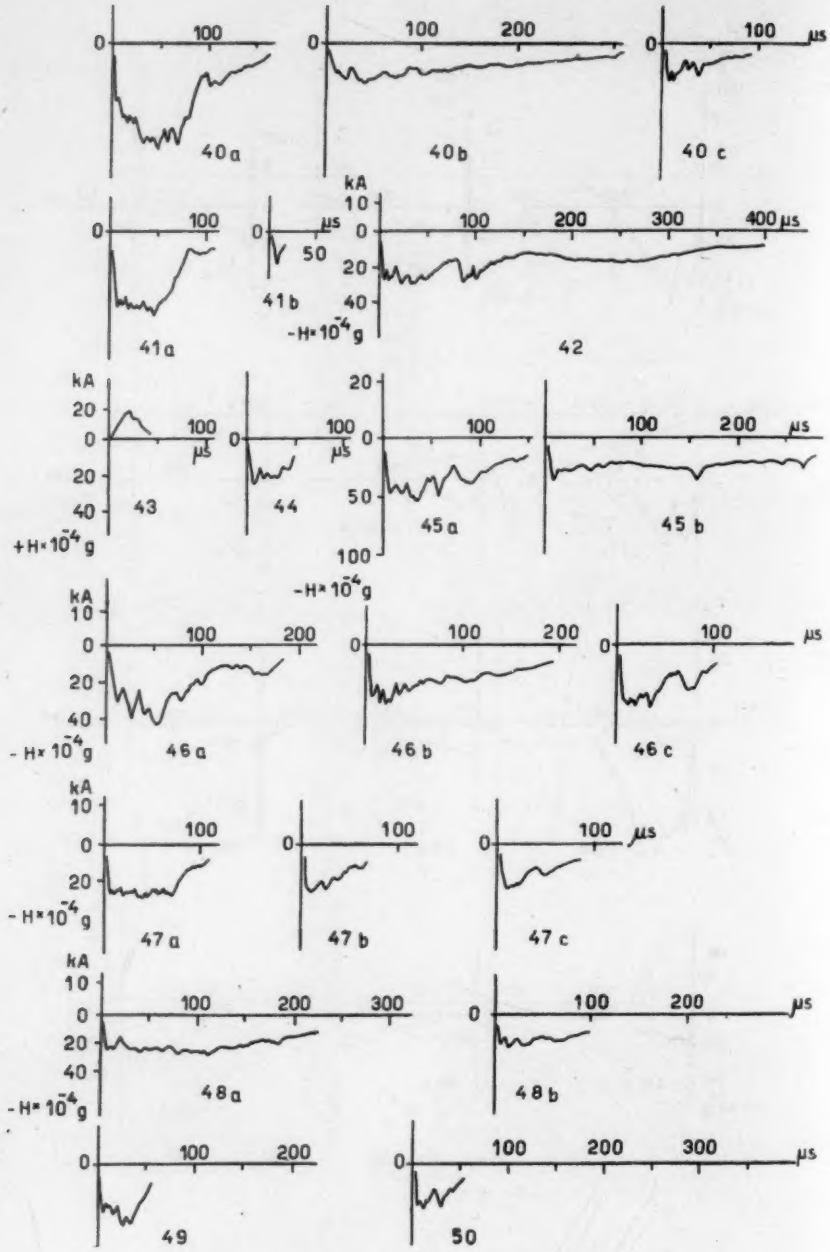

FIG. 58. Typical lightning current variation curves.

An examination of the curve material results in very characteristical features, which are mainly typical with regard to steep fronts. The rise in the front corresponds to the rapid and decreasing velocity of the lightning when proceeding from the nearest regions of the ground towards the charges descending from the cloud. As we must calculate with some damping effects, the first part of the current rise as generated in the vicinity of the ground must be faster, as we can figure from the values of the curves. In Fig. 59 the values are compared with some recent values from the United States recorded in quite another manner (11, 12, 13). The percentage time distribution of attaining the first

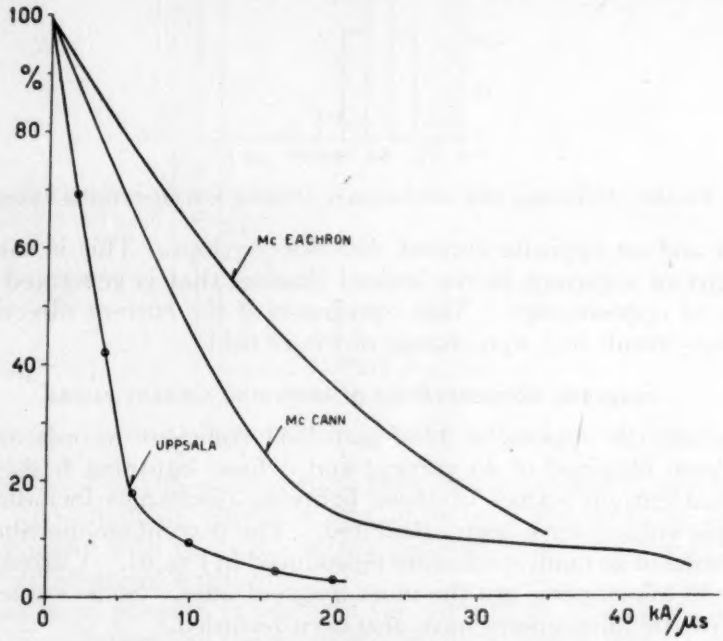

FIG. 59. Percentage distribution of rates of current rise.

crest value of the front is reproduced in Fig. 60, from which follows 5–6 µsec. as the most frequent value.

A comparison of the variation forms of consecutive multiple strokes in the same path often results in clearly alike forms of the consecutive discharges. Types of that kind are exemplified by Fig. 48, 4–4b, Fig. 50, 13a–13c, Fig. 51, 14a–14d, Fig. 52, 19a–19d. The two latest discharges of Fig. 52, 19c and 19d are of special interest. They show a typical retardation of their fronts. It seems that they have developed from an intermediate not fully extinguished ionization stage in the channel.

Sometimes marked differences in intensity of consecutive discharges are visible, see Fig. 49, 10a against 10b–10d, Fig. 50, 13a against 13b

and 13c, Fig. 51, 14a against 14b–14d. The explanation is a successive decrease in the intensity of the current delivering charges of the cloud.

Of special interest is the change of polarity in certain discharges. There are cases when the *H* curve during a certain lapse of time of its duration indicates the current direction to earth of a negatively charged cloud. At a certain moment the discharge procedure is suddenly con-

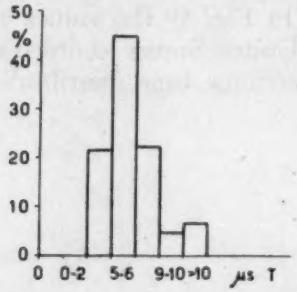

FIG. 60. Percentage time distribution of attaining first crest frontal values.

verted and an opposite current direction devlops. This is caused by the start of a current in the ionized channel that is generated from a charge of opposite sign. This conversion of the current direction will obviously result in a sign change of the *H* field.

GRAPHICAL REPRESENTATION OF LIGHTNING CURRENT VALUES.

During the seasons of 1940 and 1941 sufficient records and data have been obtained of 46 vertical and defined lightning flashes. The maximal current values of these lightning discharges including their multiple strokes have been calculated. The percentage distribution of the results of 46 main strokes are reproduced in Fig. 61. Current values up to 40 kiloamperes are the most frequent ones. Some values of the order of 100 kiloamperes have also been recorded.

From the oscillograms it was also possible to analyze and calculate

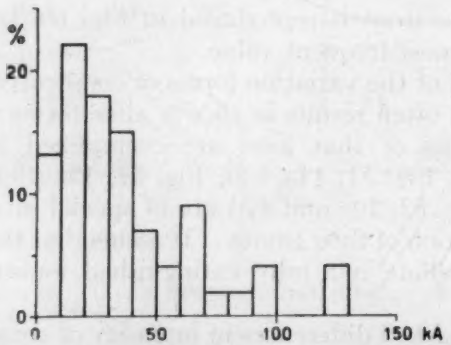

FIG. 61. Percentage current distribution of 46 main vertical lightning strokes.

60 multiple strokes following the main discharges. Combined with the foregoing current values they are represented by the distribution of Fig. 62. With reference to the successive decrease of consecutive discharges current values with lower amplitudes will be more frequent. It will be kept in mind that the observation method by operating the oscillographs at one level of voltage sensitivity will to some extent give

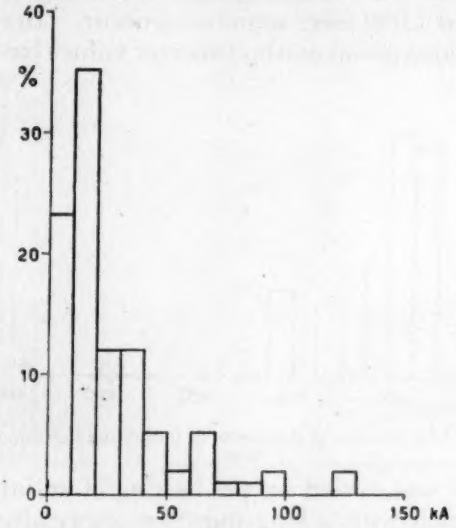

FIG. 62. Percentage current distribution of 106 main and multiple strokes.

a certain favor to the occurrence of crest current values at greater distances. To eliminate this it would have been necessary to operate simultaneously with two cathode ray oscillographs regulated at a convenient difference of sensitivity.

It has been possible to estimate the number of multiple strokes in 138 lightning flashes and the result is reproduced in Fig. 63. It appears

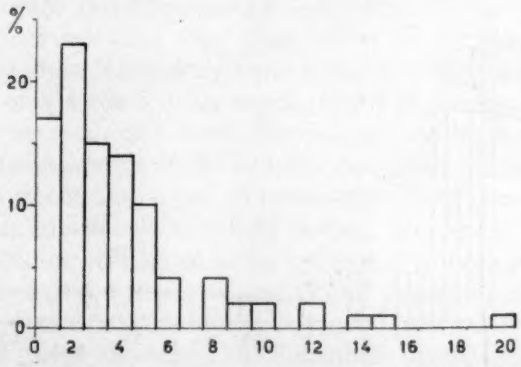

FIG. 63. Percentage distribution of number of strokes in 138 vertical lightning discharges.

evident that up to twenty strokes have been recorded and the most occurrent values are going up to five.

The duration of individual strokes has been measured and their distribution is reproduced in Fig. 64. It must be observed that the real duration time must be insignificantly longer depending on the fact that weaker parts of the currents are hidden at the zero deviation region of the oscillograph. The values usually occurring are of 100 to 200 μsec. Values up to 1,000 μsec. sometimes occur. In our earlier observations with the frame aerial method shorter values have to some extent

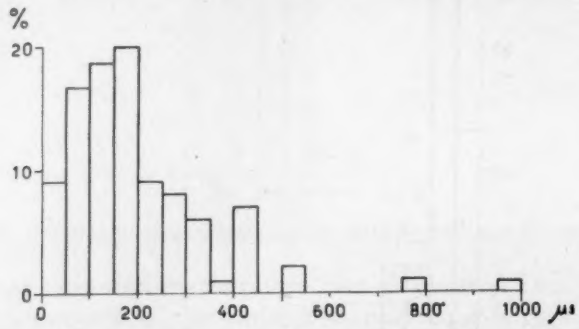

FIG. 64. Distribution of durations of individual lightning strokes.

been noted, which was caused by the lacking of an integrating method. The discharge region with a long duration, especially characteristic of the descending parts, caused slow variations in the magnetic field. Thus too small dH/dt variations followed and it was not possible to obtain a record of them. It is referred to what will be remarked further on with regard to the time interval of subsequent lightning discharges.

The measured current values combined with the corresponding time of duration have permitted a calculation of the charges in each partial discharge. The obtained coulomb values are reproduced in Figs. 65–66, of which the first figure contains values of the main strokes

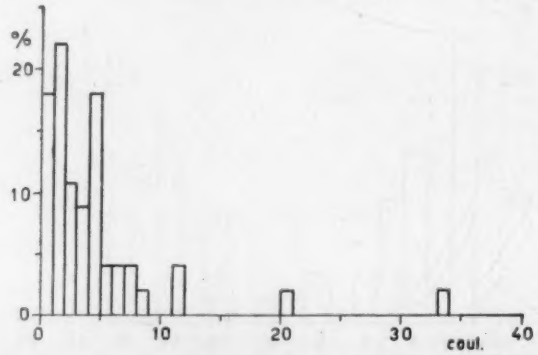

FIG. 65. Distribution of transported charges in main strokes.

and the latter of all subsequent strokes. The most prominent values in the main strokes vary up to 5 coulombs. Some values from 10 and up to 35 coulombs also occur. If the subsequent strokes are included in the calculations we obtain as follows from the decreasing intensity of subsequent strokes lower values. The distribution is in full agreement with corresponding results obtained by other methods.

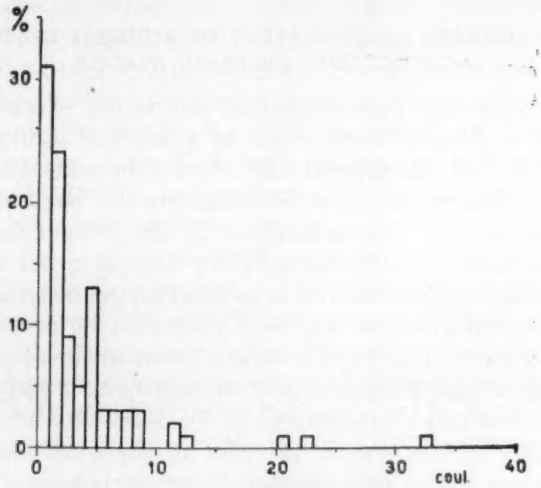

FIG. 66. Distribution of transported charges in main and partial strokes.

Of special interest is the polarity of the clouds. In the recorded strokes only three main strokes have been positive, thus passing from a positive cloud charge to ground. The positive main strokes were all very weak with current values up to a few kiloamperes. The following multiple strokes were also emanating from a positive charge with very low intensities. The lightning flashes transporting currents from ground to a negatively charged cloud were preponderant in the total observation material and comprised 93 per cent.

We have observed that the time intervals between subsequent lightning strokes show variations from some ten microseconds and up to some tenths of a second. An exact record of the total duration of the discharge process should have afforded an oscillographic recording procedure with time sweeps of the order of a second. This follows from what has already been remarked in connection with the investigations of the variations of the electric field force. Evidently such a slow-moving time velocity will be of a very limited value and the method should have prevented a study of individual current pulses. We are aware of the fact that our data are not complete with regard to the problem of the total duration of lightning discharges. The very problem in this respect is on the other hand to determine the proper

limits between which we have to estimate the duration of a lightning discharge. In connection with the investigations of the electric field variations from a lightning discharge it was stated a whole sequence of discharge procedures connected with a lightning discharge. From these points of view we are not able to consider the total duration procedure of a lightning discharge to have a fixed meaning and to be a problem of important physical interest.

OSCILLOGRAPH INVESTIGATION OF A DIRECT IGNITING AND KILLING LIGHTNING STROKE.

It has always been a very important aim in our experimental efforts to obtain such a measurement value of a vertical lightning discharge between a cloud and the ground that should be considered as typical. We will in this chapter describe how accidentally such an opportunity became offered to us. Investigations of the properties of lightning discharges especially in such cases, when high structures were struck, have always raised certain doubts as to whether such strokes are typical. The very important question will be if they may be pertaining to a full reproduction of strokes that are hitting a point in the open flat country. Strokes hitting a high structure will obviously to a very considerable extent be influenced by an external and local disturbance of the electric field conditions that are not at all valid to the same extent when the strokes take their paths in a regular direction between a well-defined cloud and a flat open country field. The importance of this question is especially proclaimed, when we have to deal with the disturbance effects of a lightning stroke with regard to high transmission lines.

There is also another feature of a lightning discharge that must be considered in this connection. From the experience when strokes are hitting objects on the earth, it is possible to separate them in two classes. The first and most predominant will be the cold lightning stroke, followed by typical splitting effects, the second the warm stroke, which is easily igniting inflammable objects. The difference between these two groups is supposed to be a question of the duration of the current and of its intensity. Splitting effects should originate from short current pulses and igniting ones from strokes of long duration. Laboratory tests are indicating these differences but a non-objectionable experiment in a local position in the open free air under full thunderstorm conditions has never been carried out earlier on. A very scarce and especially favorable opportunity to study this problem presented itself during a thunderstorm of the season of 1940.

One of the field station wagons of the Institute was operating with the frame aerial equipment. The frame had the most suitable direction for a thunderstorm center in a westerly direction and outside the field station two observers were occupied with the determination of distance and the direction of the lightning discharges. Meanwhile a

typical and limited thunderstorm cloud was developing and towering in a northwesterly direction with a distance of between 3 and 6 kilometers. The cloud appeared in a very threatening aspect, and I told my assistants to direct the frame in favor of the cloud. My assistants answered that the cloud had not yet produced any lightning and to leave the other cloud should be to spoil very favorable recording opportunities. My opinion happened to be a contradictory one. From 30 years' experience of thunderstorm observations I was aware of the fact that the very single cloud type, if the circumstances were favorable, might produce one single or a few discharges. It was also a well-known experience that the first stroke from such a cloud type very often was characterized by heavy discharge effects. A little while later I had a very fine opportunity to observe the cloud at a distance of 4 kilometers from the Institute. At $14^h56^m12^s$ I observed a very well-developed lightning flash between the cloud and the ground. I was hoping that just this very lightning flash, which showed an exceptionally regular path, had been recorded at the field station. I was not able to observe any more lightning flashes from the cloud. My general visual impression was that the flash was of a comparatively long duration. At the field station two independent observers reached the same values for distance, height and angular direction of the lightning. The distance was 4.5 km. from the observation point. This was the most suitable value for the calculations.

We were quite soon able to find that this lightning had a very tragic consequence. The hitting point of the stroke was an open grass-grown field. There a farmer was standing on a loaded hay-cart talking with his helpmate standing aside. The lightning stroke killed the farmer (see Fig. 67). His helpmate became unconscious. The farmer's dress and the wagonload of hay were set on fire. People turning up at the place tried in vain to rescue the farmer, whose body showed severe burns. The farmer carried a watch with a metallic chain, and both the watch and the chain showed very typical melting traces. There was no doubt that the lightning stroke took its way along the chain and the watch. A chain of similar type was tested with the current impulse generator of the Institute. With a current impulse of a considerable duration and of the same crest values as were stated from the damaging stroke we received quite similar melting traces. A horse that was put in the shafts of the wagon fell down on his knees at the stroke. He was taken out of the shafts and raised himself after a shout. The horse walked a few steps, began to eat grass but fell down dead after a little while.

It was of importance to examine the region of the ground more closely where the stroke hit. The ground was very homogeneous and consisted of a thin layer of cultivated soil on a deeper layer of clay. By measuring the values of the earth resistance at the point of the stroke

we found a value of 10.5 kiloohm/cm. Other measuring points at a distance of 25 m. around the place showed lower values varying between 3 and 6 kiloohm/cm. A new control measurement nine months later on gave a value at the point of the stroke of 6 kiloohm/cm. The soil

FIG. 67. Igniting and killing lightning flash as observed from a typical thunderstorm cloud.

had beyond all doubt to some extent been dried by the fire, a circumstance that may explain the higher resistance. Hence the resistance conditions at the point of the stroke do not give any indication as to why the stroke should hit just that point.

Within a region of at least 300 meters the farmer standing on his hay-cart was the highest object in the surroundings—a quite flat open field. It is not easy to find out to what extent the disturbed field conditions may have influenced the initial leaders of the stroke to hit just the very point, where the hay-cart and the farmer were standing.

The field station was operating on the damaging lightning stroke at a most suitable distance and under very well defined conditions. We had the favor to catch the lightning itself with the frame aerial and two cathode ray oscillographs, one operating on a rapid time axis and the other on a slow-moving one. The two original oscillograms obtained are reproduced in Figs. 67–68. From the slow-moving time axis of Fig. 68 it follows that the discharge consisted of two subsequent current pulses that carried different crest amplitudes. The time difference between the two strokes was 9.5 milliseconds.

The oscillogram of Fig. 69 is laid out and reproduced with the corresponding calculated current values in Fig. 69. The two current pulses have a pronounced difference both with regard to amplitudes, variation structure and duration. The discharge with the lowest intensity attains a crest value of 5 kiloamperes with a visible duration of 200 μsec. An extrapolation from the continuing decrease towards zero will give a total duration value estimated to be about 300 μsec.

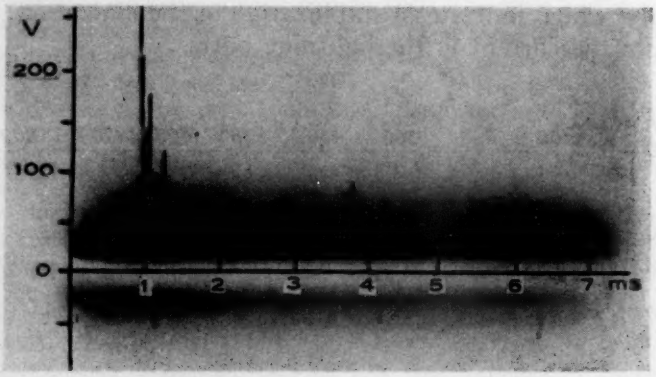

FIG. 68. Oscillogram with slow-speed time variation of igniting and killing lightning flash.

The other current pulse with the higher crest value of 800 μsec. visible in the oscillogram and a corresponding estimation of its reaching of the zero value will result in a total duration of about 1,000 μsec. The highest crest value 22.5 kiloamperes occurred after 20 μsec. The first peak of the magnetic field was reached after 10 μsec. The visible length of the lightning path as measured from angular agreeing observations from observers was 0.9 kilometers. If we calculate with a mean

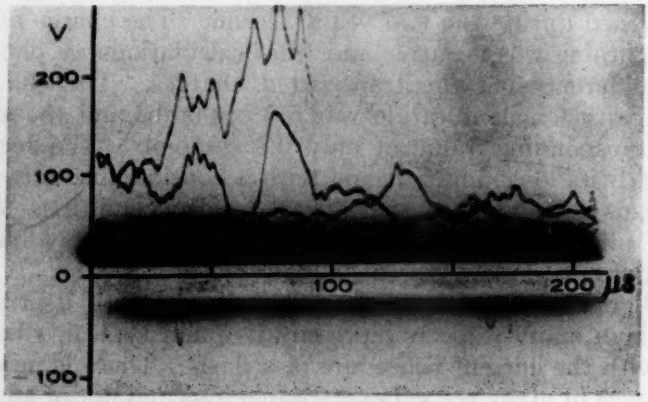

FIG. 69. Oscillogram with high-speed time variation of igniting and killing lighting flash.

value of the penetration velocity of the return main stroke of 100 μsec. in reaching the lower base of the cloud we will come to a length of 1 kilometer and thus in good agreement with the otherwise measured value of 0.9 kilometer. At the beginning of the discharge current variation values of 1 kA/μsec. were occurring. After 100 μsec. the current decreased to a lower mean value of about 5 kiloamperes. Marked increases in the current variation are visible at a time of 175 μsec., 400 μsec. and 675 μsec. Later on the current flows more continously, which indicates a stabilization of the ionization, necessary to maintain the current in the lightning path.

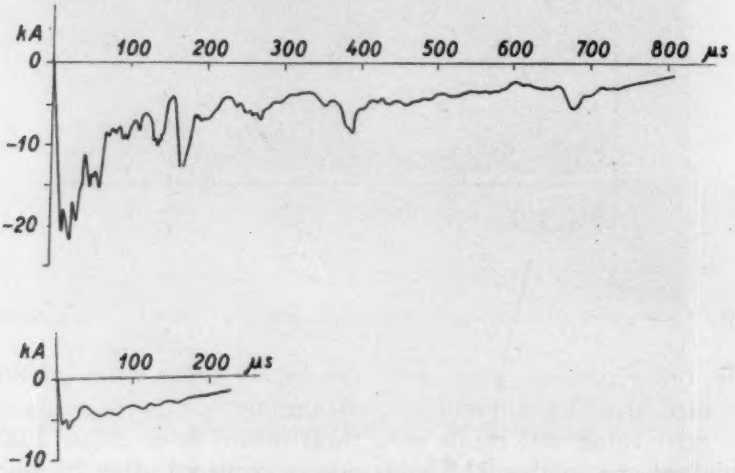

FIG. 70. Current variation values in the igniting and killing lightning flash.

The main current impulse of the flash, which was so extreme from many points of view, was also extreme with regard to duration time. The lightning stroke happened to be the one with the longest duration oscillographed during the two years' season. The charge of the cloud in this lightning was negative and from calculations we obtained very marked differences in the transported charges. The charge of the lightning with longer duration was 5.9 coulombs and the shorter one had a corresponding value of only 0.8 coulomb. The recorded discharge with its long duration and with a considerable current flowing will give us full evidence that the necessary conditions for igniting effects of a lightning stroke must be both a comparatively long duration in time and not too low current values.

The lightning flash described in detail and with its tragic consequences is in many respects representative and typical, when we have to deal with the current procedure of a flash. There is no doubt that the flash was in many respects very dangerous and not of an inoffensive feature.

The variation structure of this damaging discharge, which can be considered as a real outsider in the big family of lightning flashes, can be effectively employed when we have to deal with some important problems listed with protective devices against lightning.

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Data Radioed Back by V-2 Rocket.—A 15-pound electronic device has been developed by General Electric Company engineers to snatch valuable scientific and operating information from speeding rockets before they crash to destruction. Enclosed in the instrument section of a V-2 rocket launched from the Army Ordnance Proving Ground, White Sands, N. Mex., in recent tests, the telemetering equipment transmitted 28 items of information to the ground each 1/35th of a second.

The unusually compact and light weight device radioed to automatic recording equipment in a trailer near the launching site, measurements of acceleration, position of control vanes, fuel pressure, as well as scientific data on temperature of the rocket skin and other facts.

Less than one-sixth the weight of comparable previous telemetering devices, the equipment was developed in the G.-E. electronics laboratory. It samples 28 recording instruments by means of a highly sensitive device driven by an electric motor. Transmitted to the ground from the 3800-mile-an-hour missile, the information is recorded permanently on film by automatic motion-picture cameras.

The device is enclosed in two metal cans, four inches in diameter and 15 and 12 inches long. It is listed by engineers as "expendable," since all equipment in the V-2s is destroyed when the 46-foot missile strikes the ground at approximately 2,200 miles an hour.

All of the information is transmitted to the ground receiver over only one radio frequency, engineers said. Although the equipment used recorded 28 different items of information, it can be altered to record two or three times as many measurements without doubling or tripling weight or size.

Walter Hausz, head of the guidance and control group of the G.-E. guided-missile research program for the Army Ordnance Department, who visited England, France, and Germany in 1945 to inspect telemetering devices developed in those countries, explained that all comparable previously existing equipment weighed more than 100 pounds and incorporated more than 30 electronic tubes. The G.-E. equipment uses only 10 tubes.

The telemetering equipment, according to engineers, can be used not only in guided-missile research but in recording performance data during test flights of high-speed aircraft.

R. H. O.

THE USE OF C^{13} AND C^{14} IN MEDICAL RESEARCH.*

BY

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You have undoubtedly heard that isotopes are being used as tracers in medical research and may have wondered how they are used and why they are important.

They are important for this reason. We would like to know what happens to foodstuffs in the body. However, if we feed starch there will be excreted in the normal animal only carbon dioxide and water. If we feed protein, about the only things to be excreted are carbon dioxide, water and urea. We would like to know what intermediate products are formed by the normal organism and whether the same intermediate products are formed by the pathological organism.

Many attempts have been made in the past to "tag" molecules so they could be traced through the organism. In only a few cases has the attempt succeeded. The most successful tagging was carried out in 1904 by a German professor named Knoop,[1] who labeled some fatty acids by attaching a benzene ring to the carbon farthest from the carboxyl group and then fed them. The reason why such molecules were tagged in the animal is that the benzene ring cannot be broken down by the body and cannot be split from the last carbon. The resulting compound was excreted combined with glycine.

Figure I shows how the experiments were carried out. The acid with a single carbon attached to the benzene ring is called benzoic acid. This is combined with glycine in the body to form hippuric acid which is excreted and easily isolated and identified.

When the acid containing one more carbon atom, phenyl acetic acid, was fed, it was excreted combined with glycine. The compound is called phenyl aceturic acid. But when the next acid was fed, phenyl propionic acid, with three carbons in the side chain, hippuric acid was excreted proving that two of the three carbons of the side chain were split off in the body. The next acid to be fed, phenyl butyric acid, was excreted as phenyl aceturic acid, proving that two of the four carbons of the side chain had been split off. The last acid to be studied, phenyl valeric acid, was excreted as hippuric acid. This could be explained by assuming that two groups of two carbons each had been removed from the molecule which was fed.

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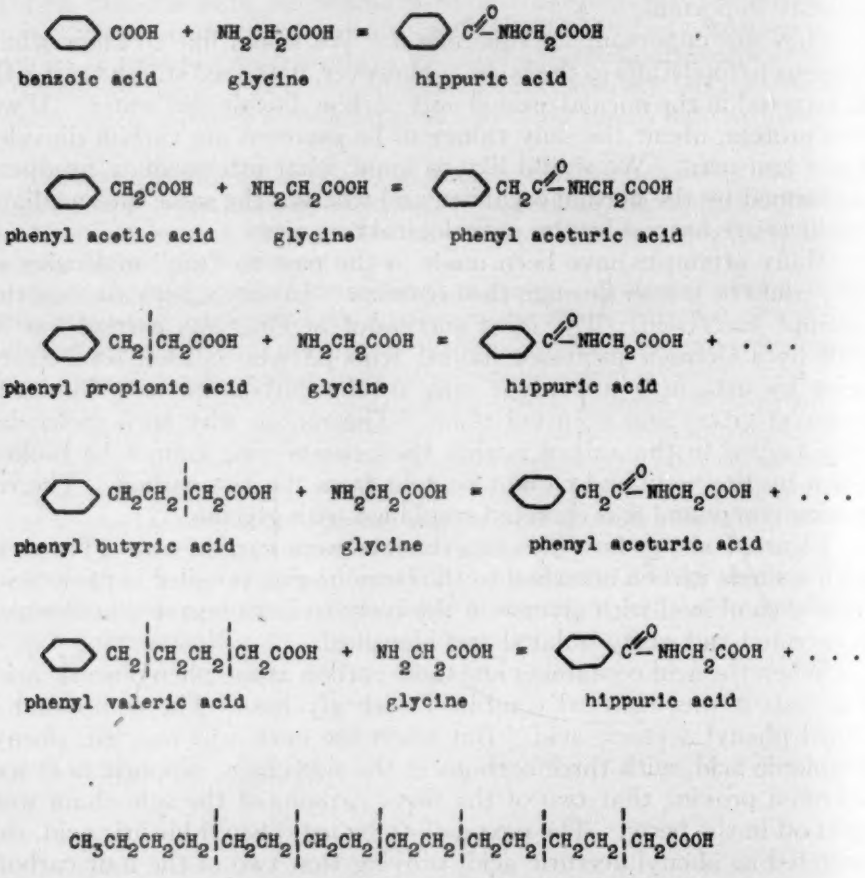
* Presented before The Franklin Institute, May 7, 1947.

[1] Knoop, F., Beitr. z. chem. Phys. u. Path., 6, 150 (1904).

These experiments suggested to Knoop that when a long chain fatty acid is oxidized, two carbons are split off at a time. This could occur if the second carbon from the end was first oxidized and then a split occurred as shown at the bottom of the Figure. Knoop thought the two-carbon groups did not combine. This is commonly called beta oxidation which means oxidation of the beta carbon atom. Knoop's

FIGURE I

Evidence for Knoop's Theory of Beta Oxidation



theory of beta oxidation has been widely accepted for many years. It is based, as we have seen, on experiments involving the tagging of carbon atoms with a benzene ring.

One difficulty with this type of labeling is that the body often refuses to change the compounds at all, and thus the experimentation is stopped. Another difficulty is that abnormal compounds are formed in some

experiments and one is not always sure that normal bodily reactions are being observed.

But with the discovery of the isotopes of the lighter elements new tools became available for research in medicine and biology. What is an isotope?

There are over 90 chemical elements. Many of these elements exist in two or more modifications which have nearly identical chemical properties but are different in some of their physical properties.

Take for example, hydrogen. Water is made up of hydrogen and oxygen. Most of the hydrogen has an atomic mass of 1. But a small amount (.02 per cent.) of it has an atomic mass of 2. This is sometimes called heavy hydrogen or deuterium. Heavy hydrogen weighs twice as much as ordinary hydrogen. Although they differ so much in weight, their chemical properties are identical. Now actually there is a third form of hydrogen which has an atomic mass of 3. Each atom weighs 3 times as much as an atom of ordinary hydrogen but it has all of the chemical properties of ordinary hydrogen. All of these different kinds of hydrogen will form water with the formula H_2O. These modifications of an element which differ in some physical properties but are identical in chemical properties are called isotopes.

Physicists in the last ten years have not only isolated and identified many isotopes but have also explained theoretically the reasons for the physical differences and the chemical similarities. Within recent months you have probably heard about heavy carbon. Ordinary carbon has an atomic mass of 12 and heavy carbon has an atomic mass of 13 so we commonly call these isotopes C^{12} and C^{13}. H^1 and H^2 and C^{12} and C^{13} are stable isotopes.

In 1934, the daughter of Madam Curie, Eve Joliot-Curie, and her husband discovered that alpha rays from radium, when allowed to bombard a target of boron, caused it to be changed to a radioactive isotope of nitrogen. This experiment established one revolutionary conception and confirmed another. First, artificial radioactivity could be produced. Second, the transmutation of elements was possible (Rutherford 1919).

The hopes of the old alchemists were finally realized, long after the last of them had disappeared. But instead of enriching a few people by making gold from cheaper elements, scientists had discovered something far more important—some of the secrets of the nuclear structure of the atom. Since then many new radioactive elements have been made artificially, including three radioactive isotopes of carbon, Fig. II.

Let us look at the structure of the atom as it has been worked out in recent years, mainly since artificial radioactivity was first discovered. Most simply stated, matter is composed of neutrons, protons and electrons. Nearly all of the weight of an atom is in its nucleus. Here we have protons (positively charged particles) and neutrons (uncharged

FIG. II. Isotopes of carbon.

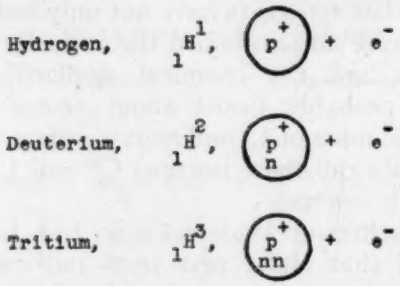
Isotope	Abundance Atoms %	Half-Life	Preparation
C^{10}	—	8.8 sec.	${}_5B^{10}(p, n){}_6C^{10}$
C^{11}	—	21 min.	${}_5B^{10}(d, n){}_6C^{11}$
C^{12}	98.9	—	
C^{13}	1.1	—	Thermal Diffusion Chemical Exchange
C^{14}	—	5000 years	${}_7N^{14}(n, p){}_6C^{14}$ ${}_6C^{13}(d, p){}_6C^{14}$

particles). The electrons are negatively charged and are rotating rapidly around the nucleus and are in number equal to the protons in the nucleus and balance exactly the charges carried by the protons. Therefore, the atom is electrically neutral.

Ordinary hydrogen contains only one proton in its nucleus (Fig. III). It has one electron flying around the nucleus like the earth around the

Figure III

The Isotopes of Hydrogen



sun. This electron in some ways gives the atom its chemical properties. Heavy hydrogen (deuterium) contains one proton and one neutron in the nucleus and one outside electron. Tritium, ${}_1H^3$, contains one proton and two neutrons in the nucleus and one outside electron.

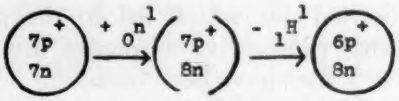
Methods of preparation. C^{14} may be made in minute amounts by the cyclotron but it can be produced in far larger quantities in the uranium pile. The great advantage of the pile over the cyclotron is that the clyclotron can prepare only traces of radioactive material while the pile can prepare it in milligram or gram lots. In descriptions of the pile, you may remember that it is so effective because the neutrons given off by Uranium 235 in the pile are slowed down by alternating layers of graphite and Uranium 235. The apparent size of the neutron is increased by decreasing its velocity and these larger neutrons can more frequently hit the target, the nucleus of the atom exposed for bombardment.

C^{14} is prepared from calcium nitrate. When calcium nitrate is placed in the pile, an occasional neutron hits a nitrogen atom and disrupts its nucleus. A proton is knocked out and the neutron is retained. The reaction which occurs is shown in Fig. IV. This is a real transmutation of elements. Nitrogen is changed into carbon and the carbon is radioactive. The radioactive carbon loses an electron ($_{-1}e^{0}$) from the nucleus, as a beta ray, and the carbon is changed back into nitrogen. It takes 5,000 years for half the atoms to disintegrate. The rays are weak, so only a little protection is needed to keep the human workers from harm.

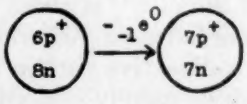
FIGURE IV

Formation and Disintegration of C^{14}

$$_{7}N^{14} + {}_{0}n^{1} = {}_{6}C^{14} + {}_{1}H^{1}$$



$$_{6}C^{14} = {}_{7}N^{14} + {}_{-1}e^{0}$$



I was asked to go down to Oak Ridge last summer to receive one of the first portions of C^{14} to be sold by the government to private investigators. I assumed that I would meet there some dozen scientists all of whom would be sold samples of C^{14} which they had ordered. When I reached Oak Ridge and received one permit after another to get through this gate and that, I found that, in the delegation, there were half a dozen scientists and some 25 or 30 newspaper correspondents and photographers.

We visited the Clinton Laboratories where, in one building, was a small uranium pile some two stories high. In this pile many radioactive elements were being prepared. Here we were shown how irradiated substances were handled. Material such as $Ca(NO_3)_2$ was placed in small metal vials which were stacked in a metal box some 6

inches square and a foot long. This box was pushed through an opening in the three-foot concrete wall which kept the radiations in the pile from escaping. After a sufficient length of time, the metal box was drawn out by means of a long poker which screwed into the end of it. It was drawn out into a box made of lead open at both ends.

Many radioactive elements are so active, "hot" they call them, that the only effective protection against the rays is a six inch layer of lead or three feet of concrete. But in all cases, distance from the active material is an important item. To remove the "hotter" of the artificially produced radioactive elements from the metal box, the small metal vials containing the material were lifted out by means of a long glass tube bent down at the end to which was attached a soft rubber ring. By providing suction to the near end of the glass tube the suction produced at the rubber ring was sufficient to permit it to attach itself to a metal vial which could then be lifted out by an attendant at a distance and be placed in a lead-shielded carrying case.

The case could then be taken to another laboratory building where, by remote control, behind a three-foot wall of concrete, chemical manipulations were carried out which led to the purification of the element desired. Many radioactive elements are prepared in this laboratory. Therapeutic uses have been found for a few. Radioactive P^{32} is used in diseases of the blood forming organs. Radioactive I^{131} is used in some abnormalities of the thyroid.

You may be interested in knowing that we bought for $400 about 100 mg. of $BaCO_3$ which contained one millicurie of activity, i.e. it gave off 37,000,000 rays per second. This would continue indefinitely, that is, indefinitely as far as we are concerned. It is calculated that the activity decreases slowly; the half life of C^{14} is about 5,000 years. We obtained enought to run somewhere between 100 and 200 experiments.

I have already indicated how radioactive carbon is prepared. The stable isotope, C^{13}, is not made, it is merely concentrated. All ordinary carbon contains about 1 per cent C^{13} and 99 per cent C^{12}. There are several methods available for concentrating C^{13} but two are commonly used. One method employs a long tube containing a gas with carbon in the molecule such as methane, CH_4. The tube, which may stand 30 or more feet high, has a heated rod running down the center and is cooled on the outside. As the gas rises at the hot surface and falls at the cool surface, the heavier methane ($C^{13}H_4$) tends to accumulate at the bottom and the lighter gas ($C^{12}H_4$) rises toward the top. The mixture containing an excess of the heavier $C^{13}H_4$ is drawn off from the bottom, burned to CO_2 and stored as $BaCO_3$. The preparations may commonly contain as much as 10–15 atoms per cent. excess C^{13}, i.e. the carbon present contains 10–15 per cent. of C^{13} in excess of the normal abundance which is 1 per cent.

Chemical methods are also available for separating C^{13} from C^{12}.

The two methods now being used involve the reactions

$$HC^{12}N(g) + C^{13}N^- \rightleftharpoons HC^{13}N(g) + C^{12}N^-$$
$$C^{13}O_2(g) + HC^{12}O_3^- \rightleftharpoons C^{12}O_2(g) + HC^{13}O_3^-$$

The preparations containing C^{13} or C^{14} are used for synthesizing compounds containing the isotopes. The compounds can then be fed to animals and followed in the organism. These compounds are difficult to make so that only relatively simple substances containing either C^{13} or C^{14} have as yet been prepared for experimentation. For instance, we are not yet able to feed tagged protein, fat or carbohydrate in quantity, but we can feed simpler, related compounds. These compounds have been synthesized by organic chemical procedures or by micro organisms. The more complicated isotopic compounds can be made by plants or animals but there is sometimes great dilution of the isotope.

Methods of analysis. The analyses for C^{13} and C^{14} are carried out in complicated physical machines. One reason for the complication is that in each case very small electric currents are produced which must be amplified many times in order that they can be measured.

C^{13} is measured with a mass spectrometer. An ordinary light spectrometer causes a ribbon or beam of light to pass through a wedge of glass which bends the light rays, the short ones most and the long ones least, producing a spectrum. In like manner, a mass spectrometer causes a ribbon of ions of gas to pass down the tube where it meets a magnetic field which deflects the charged particles. The lighter ones are deflected the most. If there were present in the tube carbon dioxide ions from both $C^{12}O_2$ and $C^{13}O_2$, the ions from $C^{12}O_2$ would be deflected more than those from $C^{13}O_2$. Two ribbons or narrow beams of ions would result and the relative amounts of C^{12} and C^{13} in these two beams can be determined.

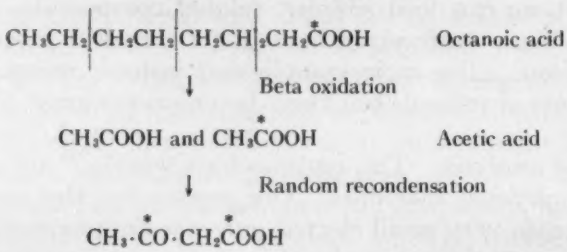
$C^{14}O_2$ can be measured in the same way but it is simpler to measure its radioactivity with a suitable instrument such as a Geiger counter.

It has often been extremely difficult in the past to demonstrate whether or not one compound is changed into another specific compound in the animal body. Knoop's experiments already mentioned, in which a benzene ring was used to tag fatty acids, were so unusual as to be classics. More satisfactory tagging is now becoming possible with the use of isotopes, with which one can label certain atoms in a molecule and follow them through the organism. Advances were made first by the use of heavy hydrogen. Then heavy nitrogen revolutionized our knowledge of protein metabolism. These studies were made by Schoenheimer and his group at Columbia. We have just become well embarked on what may prove to be the most important study of all, the study of carbon metabolism with C^{13} and C^{14}. All of our experiments can be done with either C^{13} or C^{14}. C^{14} has the advantages that

it can be more readily tested for, is not found in nature in appreciable amounts, and it is cheaper to use per experiment. Hastings of Harvard used C^{11} until C^{14} became available.

In addition to feeding experiments on animals, it is often possible to run experiments with tissue slices, homogenates or extracts in which enzyme systems may be studied outside the animal body. Weinhouse, Medes and Floyd [2] (in 1944) were the first investigators to make extensive studies on fat oxidation by means of a carbon isotope (Fig. V). They

FIG. V. Acetoacetic acid formation from fatty acids.
(Weinhouse, Medes and Floyd)



introduced C^{13} into the carboxyl group of octanoic acid, an 8-carbon fatty acid which is similar to and easier to work with than the natural long chain fatty acids which contain 16 and 18 carbon atoms.

When isotopic octanoic acid was allowed to react with enzymes in liver slices, it was found that acetoacetic acid was formed with the isotope distributed equally between the carboxyl and carbonyl carbons. The conclusion was drawn that when octanoic acid was oxidized, groups containing two carbon atoms were split off. These two-carbon units combined randomly to form the four-carbon compound, acetoacetic acid. If they combined randomly some molecules of acetoacetic acid would contain no isotope, some would contain isotope in one group, some in the other group and some in both groups as shown in Fig. V. These experiments suggest that beta oxidation and random recombination occur.

Acetic and acetoacetic acids have been recognized for many years as products of fatty acid metabolism. It was believed that these acids could not be converted into carbohydrate in the body, but recently this belief has been challenged. We [3] have studied the problem using acetic acid with isotope in the carboxyl group.

Some of the acetic acid was allowed to digest with an homogenate of guinea pig kidney (Table I). Succinic acid was isolated and found to contain much of the isotope of the metabolized acetic acid. Succinic acid is one of the compounds formed by carbohydrates when they are

[2] Weinhouse, S., Medes, G., and Floyd, N. F., *J. Biol. Chem.*, **155**, 143 (1944).

[3] Buchanan, J. M., Sakami, W., Gurin, S., and Wilson, D. W., *J. Biol. Chem.*, **159**, 695 (1945).

TABLE I.

Metabolism of Acetate and Acetoacetate.

Experiment No. (1)	Isotopic Material Added (2)	Amount of Aceto-acetate or Acetate Metabolized (3)	Non-isotopic Organic Acid Added (4)	Dicarboxylic Acid Isolated (5)	C^{13} Concentration Atoms Per Cent. Excess		
					Initial Aceto-acetate or Acetate (6)	Dicar-boxylic Acid Isolated (7)	$NaHCO_3$ (Average Value) (8)
		mM					
1A*	Acetoacetate	0.25	Succinic	Fumaric	3.80	0.22	0.12
1B*	Acetoacetate	0.34	Succinic	Fumaric	3.98	0.30	0.01
2	Acetoacetate	0.32	α-Ketoglutaric	α-Ketoglutaric	3.98	0.50‡	0.03
3*	CO_2	0.10	Succinic Acetoacetic	Fumaric	0.00	0.00	2.28
4†	Acetate	0.31	α-Ketoglutaric	Succinic	3.88	0.28	0.01

* 60 minute experiment.

† 40 minute experiment.

‡ This value calculated from the observed C^{13} content of α-ketoglutaric acid semicarbazone.

oxidized in the body. Therefore, we must conclude that a product of fat metabolism may be oxidized as carbohydrates are, that is, by way of the carbohydrate cycle. In other experiments acetoacetic acid was used, giving similar results.

One thing that might be mentioned, however, is that there is no net increase of carbohydrate material. It would appear that a molecule of carbohydrate material is needed for the oxidation of 2 molecules of acetic acid. In the past we would say fat is not converted into carbohydrate. Now we must say fat does not cause any net increase in carbohydrate intermediates, although it enters the carbohydrate cycle.

In another experiment [4] we used a phlorhizinized rat which excretes large amounts of glucose and ketone bodies in the urine. 500 mg. of sodium lactate, labeled with C^{14} in the α or β position, were administered (Table II). Lactate administration caused a large excretion of extra

TABLE II.

Recovery of Isotope from α,β Labeled Lactate.

Substance	Counts/Min./ Mole C $\times 10^4$	Total Counts Administered or Recovered	Recovery
			per cent
Administered Lactate	26.4	3580	—
Respiratory CO_2 (4 hours)	2.16–4.55	620	17.3
Urinary Glucose (6 hours)	4.64	720	20.0
Ketone Bodies (6 hours)	—	267	7.8
Carboxyl of Acetoacetate	5.40		
Acetone of Acetoacetate	5.04		
Carboxyl of β-Hydroxy Butyrate	5.70		
Acetone of β-Hydroxy Butyrate	5.10		
Liver Fat	1.80	260	7.3
Muscle Fat	0.96	800	22.4

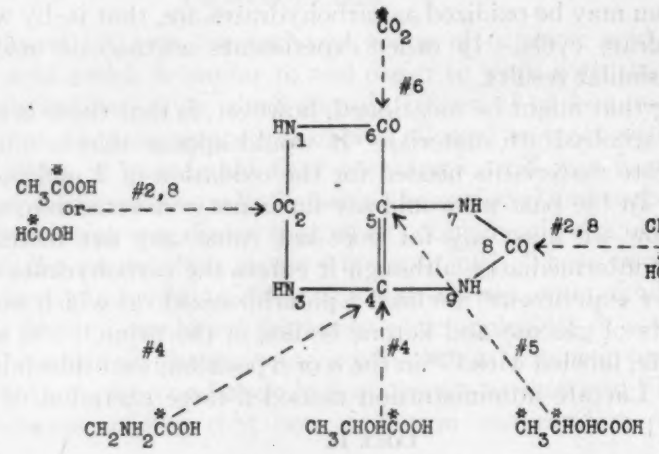
[4] Gurin, S., Delluva, A. M., and Wilson, D. W., *J. Biol. Chem.* (in press).

glucose equivalent to about 70 per cent. of the weight of lactate. However, only 28 per cent. (20 per cent. in six hours) of the isotope was recovered in the glucose. In some way lactic acid when administered causes the excretion of an equivalent amount of glucose in the glycosuric animal but furnishes less than one-third of the carbons of the glucose.

We found quite unexpectedly that considerable amounts of the isotope appeared in the ketone bodies of the urine. The isotope was distributed equally throughout the ketone body molecules as would be expected if there is a conversion of lactic acid to ketone acids by way of pyruvic acid and the two carbon compound resulting from its decarboxylation. The concentration of isotope in the ketone bodies was higher than the concentration in fat that was isolated from liver and

FIGURE VI

Precursors of Uric Acid Carbon



muscle. We may, therefore, draw two unexpected conclusions: First, lactic acid, which has been known for years as an antiketogenic substance, may actually furnish carbon for ketone body formation. Second, fats are not the only intermediates in the formation of ketone bodies from lactic acid in an experiment of this type.

Uric acid formation was studied in our laboratory [5] (Fig. VI) by using pigeons which normally excrete uric acid as the end product of nitrogen metabolism, instead of urea. An isotopic compound was fed over a period of 12 hours. The excreta were collected over this period, the uric acid isolated and degraded. The carbon was obtained from the

[5] Sonne, J. C., Buchanan, J. M., and Delluva, A. M., *J. Biol. Chem.*, **166**, 395 (1946).

various positions of the uric acid molecule and analyzed for isotope. In this way one can determine whether isotope had entered different parts of the uric acid molecule. The structural formula of uric acid is shown with the positions numbered. When isotopic $NaHCO_3$ was fed, isotope was found in No. 6 carbon only. Sodium acetate labeled in the carboxyl group caused isotope to enter positions 2 and 8. Lactate labeled in the alpha or beta positions caused isotope to enter position 5 and carboxyl labeled lactate caused isotope to enter position 4.

Glycine labeled in the carboxyl group introduced isotope into position 4. The experiments suggest that the alpha carbon of glycine enters position 5. Thus the precursors of the carbon of uric acid have been determined by means of isotopes. This is a most dramatic instance of the way in which the carbon isotope has permitted us to gain important and unexpected knowledge about the source of complicated biological materials.

This brief description of the carbon isotopes and how they are used in medical research will, I hope, give you some appreciation of their value in aiding us to learn the intricacies of the chemical processes occurring in the body. Such knowledge will be valuable in showing the relations between normal and diseased conditions.

Powerful X-Ray Machine for Industrial Use. (*Compressed Air Magazine*, Vol. 52, No. 2.)—In the Betatron, industry has, for the first time, an instrument that will enable it to examine castings and forgings for hidden flaws which have defied detection in the past and caused foundries to make certain of their products oversize or overweight so that the weakest sections would stand up in service. The Betatron is a 20,000,000-volt X-ray machine—a voltage that is accepted as the present-day limit and adequate for most industrial needs. It was invented by D. W. Kerst, University of Illinois physicist, and is being constructed by Allis-Chalmers Manufacturing Company.

The first unit has been installed at the U. S. Army Arsenal at Picatinny, N. J., and will be used to X-ray shells and rocket warheads more than a foot thick. Its rays are capable of penetrating 20 inches of steel in twenty minutes and of revealing almost microscopic flaws. Because the X-ray source is small in size, it is possible to make direct enlargement of an object by placing the film remote from it. This increases the over-all sensitivity of the radiograph and permits magnification of microparts to three or more dimensions. Further, because there is less scattering and, consequently, less fog than with lower-voltage X-rays, the definition and quality of the radiograph are higher.

The Betatron, in lay language, is a 2-winding transformer with a stream of electrons serving as the secondary highvoltage winding. The latter, instead of being made up of the hundreds of thousands of turns of very small wire that would ordinarily be required to produce 20,000,000 volts, consists of a doughnut-shaped, porcelain vacuum tube containing a sturdy filament and a tiny platinum target. This tube, together with a specially designed circular steel pole piece, is inserted into a small air gap in the center leg of the machine's steel magnet or core.

When myriads of electrons are shot from the filament in the evacuated tube, the magnetic flux acts on them much as though they were moving inside the conventional turns of wire. As the magnet is energized, the flux surrounding the the pole piece builds up and causes the stream of electrons to race round and round several hundred thousand times and at a rate finally approaching the speed of light. All this takes place in 1/720th of a second! At the peak of their travel, current from an electronic circuit upsets the magnetic field and causes the electrons to spiral off and collide with the tip of the small target. The energy given off by the electrons in their collision with the target generates a supply of high-frequency X-rays which penetrate and emerge from the walls of the vacuum tube as though it were non-existent.

Thus the Betatron, by combining a transformer winding and an X-ray tube, becomes a highly efficient tool for the scientific worker and industry. With it, to mention but one of its applications, it will be feasible to examine heavy castings and forgings on a laboratory or production-line scale and to reject even those that have the most minor imperfections, thus eliminating the present practice of oversizing. Through study of the defective parts it may be possible to redesign them with a view to reducing their weight to a point where they will still serve their purpose with an ample margin of safety.

R. H. O.

NOTE ON THE USE OF SYMMETRIC FUNCTIONS IN THE SOLUTION OF LINEAR DIFFERENTIAL EQUATIONS WITH CONSTANT COEFFICIENTS *

BY

MARTIN GOLAND † and Y. L. LUKE ‡

In many problems of applied mathematics the results sought are obtained as the solution of a system of simultaneous ordinary linear differential equations with constant coefficients, or as the solution of one such equation. When the degree of the system of equations is large, the labor required to translate the general solution into a numerical result is extensive.

When interest is concentrated on the behavior of the system over only a limited range of values of the independent variable, it is customary to reduce the numerical tediousness by seeking the solution in the form of power series. The interval of the independent variable which can be accounted for by this procedure is naturally dependent on the rapidity with which the series solution converges.

The purpose of this note is to outline a particularly simple method for establishing the power series solution under certain circumstances. By drawing on the theory of symmetric functions, the solution can be described with great facility and in a form which permits rapid numerical evaluation of the coefficients of the series.

Consider that the solution is obtained by the methods of the operational calculus. Then the Laplace transform of a dependent variable $x(t)$ is frequently obtained in the form

$$\bar{x}(p) = \frac{f(p)}{g(p)}, \tag{1}$$

where $\bar{x}(p)$ is the Laplace transform of $x(t)$; p is the Laplace operator; and $f(p)$ and $g(p)$ are polynomials in p, the degree of $f(p)$ being at least one less than that of $g(p)$. In particular, let

$$f(p) = a_0 p^m + a_1 p^{m-1} + \cdots + a_m, \tag{2}$$

$$g(p) = p^n + b_1 p^{n-1} + \cdots + b_n, \tag{3}$$

* The method described in this note was developed as part of an investigation sponsored by the Dynamics Branch, Aircraft Laboratory, Air Materiel Command, Army Air Forces, Wright Field, Dayton, Ohio.

† Chairman, Engineering Mechanics Section, Midwest Research Institute, Kansas City, Missouri.

‡ Research Mathematician, Midwest Research Institute, Kansas City, Missouri.

where $m \leqslant n-1$ and without loss of generality the leading coefficient of $g(p)$ is made unity. Equation (3) is now rewritten as

$$g(p) = \prod_{i=1}^{n} (p - p_i) = p^n \prod_{i=1}^{n} \left(1 - \frac{p_i}{p}\right), \tag{3'}$$

where the p_i are the roots of the equation $g(p) = 0$.

Provided $|p|$ is maintained sufficiently large, it then follows from an application of the binominal theorem that

$$\frac{1}{g(p)} = \frac{1}{p^n} \prod_{i=1}^{n} \left(1 + \frac{p_i}{p} + \frac{p_i^2}{p^2} + \frac{p_i^3}{p^3} + \cdots\right). \tag{4}$$

If the multiplications called for in Equation (4) are now performed, it is found that the result can be written in terms of certain symmetric polynomials in the parameters p_i.[1] The particular result obtained is that

$$\frac{1}{g(p)} = \frac{1}{p^n}\left(1 + \frac{T_1}{p} + \frac{T_2}{p^2} + \frac{T_3}{p^3} + \cdots\right), \tag{5}$$

where T_k is the sum of all the possible $\sum$ functions in the n variables p_i which are of degree k, each with a unity coefficient attached. It will be shown shortly that the various T_k can be evaluated with relatively little difficulty for a particular polynomial $g(p)$.

Returning to Equation (1) and without laboring the fairly obvious operational proofs required to justify the step, combining this equation with Equation (5) gives

$$\bar{x}(p) = \frac{f(p)}{p^n}\left(1 + \frac{T_1}{p} + \frac{T_2}{p^2} + \cdots\right) \tag{6}$$

and substituting the form of $f(p)$ from Equation (2),

$$\bar{x}(p) = \frac{a_0}{p^{n-m}} + \frac{a_0 T_1 + a_1}{p^{n-m+1}} + \frac{a_0 T_2 + a_1 T_1 + a_2}{p^{n-m+2}} + \cdots. \tag{7}$$

In its general form Equation (7) becomes

$$\bar{x}(p) = \sum_{r=0}^{\infty} \frac{a_0 T_r + a_1 T_{r-1} + \cdots + a_m T_{r-m}}{p^{n-m+r}}, \tag{8}$$

where $T_0 = 1$ and $T_k = 0$ for $k < 0$. The solution for $x(t)$ in power series form is then

$$x(t) = \sum_{r=0}^{\infty} \frac{a_0 T_r + a_1 T_{r-1} + \cdots + a_m T_{r-m}}{(n-m+r-1)!}\, t^{n-m+r-1}. \tag{9}$$

---

[1] A polynomial $F(x_1, \ldots, x_n)$ is said to be symmetric if it is unchanged by any interchange of the variables $(x_1, \ldots, x_n)$. For an exposition of the theorems relating to symmetric polynomials, and for a definition of the Σ and S functions introduced in the work, see "Introduction to Higher Algebra," by M. Bocher, The Macmillan Company, New York, 1907, Chapter 18.

Concerning the various T_k, it is shown in the standard treatments of the subject that every $\sum$ function is expressible in terms of the so-called S functions. Hence each of the T_k can be written in terms of the S functions. But Newton's Law provides a means for evaluating every S function in terms of the coefficients $b_1, \cdots, b_n$ of the polynomial $g(p)$ It follows from this that every T_k can be evaluated directly from a knowledge of the coefficients $b_1, \cdots, b_n$ attached to p in Equation (3). The algebraic details of the procedure are not explored here since they are made obvious in such treatments as that afforded by Bôcher.

With this result in mind, it is seen that Equation (9) describes the power series solution for $x(t)$ in a particularly convenient form. To evaluate numerically the coefficients of the series, only the nature of the polynomials $f(p)$ and $g(p)$ need be known.

As an example of the application of the method, consider the following set of equations which occur in a problem in aircraft dynamics,[2]

$$\frac{d^4y}{dt^4} + \alpha\, y + \beta\theta = 0, \tag{10}$$

$$\frac{d^2\theta}{dt^2} + \gamma\, y + \delta\theta = 0. \tag{11}$$

Here $\alpha, \beta, \gamma, \delta$ are constants, generally complex numbers, and the dependent variables $y(t)$ and $\theta(t)$ represent the bending and twisting displacements along the span of a wing structure vibrating in a fundamental mode. Since modes of this kind can usually be described by a rapidly convergent power series, a solution of this type is sought.

Considering the solution either of the two dependent variables by the operational method, the polynomial $f(p)$ is of the fifth degree and contains the root boundary conditions at $t = 0$. The polynomial $g(p)$ is of the sixth degree and is

$$g(p) = p^6 + \delta p^4 + \alpha p^2 + (\alpha\delta - \beta\gamma). \tag{12}$$

By the methods already outlined it is found that

$$T_1 = -\delta, \tag{13}$$

$$T_2 = \delta^2 - \alpha, \tag{14}$$

$$T_3 = -\delta^3 + \alpha\delta + \beta\gamma, \tag{15}$$

$$T_4 = \delta^4 - \delta^2\alpha - 2\beta\gamma\delta + \alpha^2, \tag{16}$$

$$T_5 = -\delta^5 + \delta^3\alpha + 3\beta\gamma\delta^2 - \delta\alpha^2 - 2\alpha\beta\gamma, \tag{17}$$

etc.

and so the solutions for $y(t)$ and $\theta(t)$ can at once be written by an application of Equation (9).

[2] "The Flutter of a Uniform Cantilever Wing," by M. Goland, *Journal of Applied Mechanics*, Vol. 12, No. 4, December, 1945.

Atomic Energy By-products.—The by-products of atomic energy may well prove of greater importance to society than atomic power itself, delegates to the "World Conference on Mineral Resources" were told recently. The conference was held in connection with the seventy-fifth annual meeting of the American Institute of Minning and Metallurgical Engineers.

These by-products include radioactive isotopes, radiation chemistry and metallurgy, and fission products, "and we shall probably realize many of their benefits more quickly" than those of atomic power produced commercially, according to a paper prepared by Harry A. Winne, General Electric vice president in charge of engineering policy, and B. R. Prentice, his assistant on atomic energy matters.

Discussing "Applications of Atomic Energy to Industry," Mr. Winne, who presented the paper, said that the production of commercially useful atomic power was technically possible, and that experimental or demonstration plants would be in operation within the next two to four years.

"We believe such production is economically feasible, at least for many special applications," said the speaker, who was a member of the State Department's Advisory Board on Atomic Energy. However, the development of economically competitive atomic power is in our estimation a long-term project, possibly requiring decades. And its advent will be gradual. We feel atomic power will supplement, but not supplant, present power sources."

The G-E official indicated that the first real commercial application of atomic energy may take the form of power plants for ships. "Atomic plants for naval and large commercial ocean vessels look definitely possible, and attractive from the standpoint of making refueling extremely infrequent."

Mining and metallurgical industries have several special reasons for being interested in the atomic age, according to Mr. Winne. He pointed out that they will be involved in the production of special materials required by atomic energy installations and processes. They also will adapt atomic power for use in the mining and refining of materials. In addition, they will find radioactive isotopes and radiation in metal and chemical processes of great value both for laboratory study and production.

Stressing the advantages of radioactivity for industrial use, the speaker explained that extremely small quantities of radioactive tracers can be detected with the aid of special instruments. By the same means it is possible to measure the amount of tracer present without removing it from a compound by chemical separation.

"Perhaps the surest widespread industrial uses are in the chemical laboratories," he said. "Since chemically and physically the radioactive isotope of an element acts exactly the same as the stable isotope of the same element, analytical techniques can determine the amount of a given element in the final product."

In order to reap all the potential benefits of atomic energy, Mr. Winne said, "It is quite evident that a tremendous amount of research and development must be carried on, and much of this lies within the scope of members of the American Institute of Mining and Metallurgical Engineers. We are sure it will be done."

R. H. O.

NOTES FROM THE NATIONAL BUREAU OF STANDARDS.*

NEW LABORATORY TO TEST GEIGER-MÜLLER COUNTERS.

A new laboratory to test Geiger-Müller Counters and associated electronic measuring equipment has been established in the Radioactivity Section of the National Bureau of Standards. Called into being by the growing demand for reliable, stable instruments, the laboratory will test performance qualities, utility, and construction of counters now being manufactured.

The fields of science dealing with radioactive matter and isotopes have grown far beyond that of physics to include biology, chemistry, and medicine, in addition to fast developing industrial uses. In all of these areas of investigation, the Geiger-Müller Counter has become a critical piece of equipment, although commercial production has been undertaken only in the past seven or eight months.

Research uses for the counters include detection and numerical measurement of particles emitted in experiments involving nuclear radiation, transmutation, and disintegration.

Many varieties of counters have been made commercially and in research laboratories. The problem of construction involves not only stability and accuracy, but also adaptation of the basic idea to the specific purposes to which the device will be put.

Because of the possible types of counters available, writing specifications for a particular instrument may be difficult for the researcher lacking the background of the physicist or the electronic engineer. The problem is further complicated by the fact that it is unusual for successive counters made even by the same manufacturer to be alike in every detail. Improvements and advances are made rapidly in this field and can quickly be incorporated in a counter under construction.

The new laboratory, in its testing, will attempt to bridge the gap between the manufacturer and the user, providing for expert determination and study of efficiency, stability, uniformity, and sensitivity of counters. Aid will be rendered to purchasers by assistance in the formulation of specifications, and to manufacturers by the accumulation of test data and by determining the type of counters necessary to various fields of scientific research.

Because of the lack of uniformity in types and design of the counters now becoming available, no attempt can be made at present to set up standard specifications for them, and the uniqueness of each instrument now being manufactured controls the immediate program outlined for

*Communicated by the Director.

the new laboratory. It is expected that cooperation between the laboratory, purchasers, and manufacturers will gradually achieve a background of experimental and operational data leading to standard types of equipment.

NEW COUNTER-CURRENT REFLUX STILL FOR ISOTOPE SEPARATION.

A new and highly efficient type of counter-current reflux molecular still for the separation of natural isotopes has resulted from wartime research at the National Bureau of Standards with the cooperation of the United States Department of Agriculture. During the course of the work, several modifications of the apparatus have been developed in connection with research on mercury isotopes.

The discovery of practical means of obtaining isotopes furnished the chemist and biologist with a powerful tool—known as the method of tracers—for the study of chemical processes, particularly those which take place within the living organism. The method of tracers uses an isotope of a given element as a "tagged atom," which may be traced through a series of chemical reactions without loss of identity. Now that quantities of previously rare artificial radioactive isotopes are available, because of recent discoveries in nuclear physics, the progress in their utilization as tracers can be greatly expedited. However, for many applications of this method the stable, naturally occurring isotope of a given element is required. The counter-current reflux still has proved to be an effective instrument for the separation of the natural isotopes of mercury, and is expected to have application to isotope work on other elements. Meanwhile, plans are being made for the application of this type of apparatus to the separation of pure hydrocarbons from petroleum and the isolation of vitamins from animal and vegetable products.

The term molecular distillation has been applied to that type of distillation where there is no return of escaping molecules to the evaporating surface. This is accomplished by operating with high-boiling (low-vapor-pressure) liquids under such high vacuum that the mean free path of the escaping molecules is of the order of the distance between the surface of the evaporating liquid and the cooled condensing surface of the still.

In molecular distillation, the relative rate of escape of the various types of molecules from a composite liquid surface are determined by two factors: (1) the vapor pressure (or the boiling point) of each component, and (2) the average molecular velocity of each component. Vapor-pressure differences among the isotopes of the heavy elements are small or nonexistent, whereas molecular velocities, at a given temperature, are inversely proportional to the square root of the atomic weights. Molecular distillation thus offers a very practical means not only for

separation of the isotopes of the heavier elements but also for the separation of any mixture of high boiling substances differing in molecular or atomic weight. The latter application is particularly useful in the separation of hydrocarbons that do not differ appreciably in boiling point or are unable to withstand the high temperatures of ordinary distillation.

Previous work on the separation of mercury isotopes, using small single-stage molecular stills, has had little practical value because of the labor involved, the time consumed, and the large quantity of mercury required. In order to obtain appreciable concentration it is necessary to repeat the process many times. This requires an elaborate system for collecting, recombining, and distilling fractions. If this is not done, a tremendous quantity of mercury would be necessary in order to separate even one gram of a single isotope.

To overcome these difficulties, a new type of molecular still was designed in which a number of single-stage stills are so connected that recombination of fractions takes place automatically by gravity feed. In this way, the necessity of making repeated "cuts," with consequent reduction in output, is eliminated. The resultant separation, realized in one operation is equivalent to the separation per stage raised to the power of the number of stages. As a result, the time and labor involved become much less than for repeated distillation in a single-stage still. For example, a separation that would have required 55 individual and recombination distillations was obtained in one step with a 10-compartment still. In addition, the quantity of mercury required is enormously reduced.

The multistage molecular still consists of a series of evaporating surfaces, or pools, set adjacent to each other but at slightly different levels. A cooled roof directly above each pool serves to condense the vapor. The roofs are so sloped that the condensate will run along the surface to fall into the adjacent cell higher up. Each pool is equipped with a spillover, which allows liquid to run back in amount equal to the condensed vapor carried forward. The over-all operation is such that the light fraction increases in concentration toward the upper end, while the heavy fraction increases in concentration toward the lower end of the still.

In addition to the great savings of time, labor, and materials effected through use of this still, there are further advantages. The operation can be made continuous; the material to be concentrated can be fed into the system at one end or at the midpoint, if both light and heavy fractions are of interest; and the concentrate can be withdrawn continuously. Furthermore, the entire separation can be run without exposing the material to the atmosphere; this is particularly desirable for liquids that are susceptible to decomposition upon exposure to air.

Work to Start Soon on Government Atomic Laboratory at Schenectady.—Construction of the Knolls Atomic Power Laboratory to be built near Schenectady, N. Y., by the Atomic Energy Commission will start this spring, it has been announced by L. E. Johnston, Area Engineer for the Commission. The laboratory is being erected under the supervision of the General Electric Company, which will operate it for the government when completed. Mr. Johnston said that scientists and engineers will probably begin to occupy the new building by the middle of 1948.

The new atomic laboratory is to be located on part of a 386-acre tract in nearby Niskayuna. On another part of the property the new General Electric Research Laboratory is now rising. The two laboratories, whose work will closely mesh, are to be operated as a unit under the direction of Dr. C. G. Suits, G.-E. Vice President and director of the Research Laboratory.

A number of scientists for the project have already been recruited, said Dr. Suits, and are at work in the present G.-E. laboratory buildings. More are being employed as rapidly as qualified men and women can be found. Physicists, metallurgists, chemists and chemical engineers—technical men of all kinds—are needed, he declared.

A number of buildings will form the Knolls Atomic Power Laboratory. In one will be located an experimental pile. Such a pile, it is expected, will form the firebox and boiler of future atomic power plants. Other buildings of the group will be devoted to offices, metallurgy, chemical engineering and chemistry. Another building will house a 3,500,000-volt electrostatic or Van de Graaff, generator, for atom-smashing studies. J. Gordon Turnbull, Inc., of Cleveland, is the architect for the new laboratory.

An earlier government announcement about the new laboratory said that its purpose would be to conduct research in all phases of atomic power development, and that in addition research on specific problems in connection with the operation of the Hanford Engineer Works in the state of Washington, now operated by General Electric's Chemical Department, would be carried on in the new facility.

R. H. O.

THE FRANKLIN INSTITUTE.

PROPOSED CHANGES IN BY-LAWS.

To ACTIVE MEMBERS:

It is my responsibility to present for consideration by the membership of the Institute the accompanying changes in the Institute By-Laws as approved by the Board of Managers on June 18, 1947. These changes will be put to vote of the active members at the stated meeting of the Institute October 15, 1947.

The establishment of the Franklin Research and Development Laboratories with research contracts involving large sums of money has called attention to the need for a professional, full-time Treasurer on the Institute staff rather than the present Treasurer, who is on a part-time volunteer basis. Also it seems desirable to make the By-Laws more flexible in keeping with the increasing activities of the Institute.

The present By-Laws require that the Managers, the President, the Vice Presidents, and the Treasurer shall be elected by the membership. The proposed By-Laws still require that the Managers be elected by the membership, but that all other officers shall be elected by the Board of Managers. This is a very standard and, in fact, almost universal form of corporate procedure.

Under the proposed By-Laws, the number of officers specified is reduced to those in a standard corporate set-up with the intention that other officers such as those specified in the present By-Laws, may be elected by the Board as may be necessary to meet current needs.

The specified duties of the officers are revised to make the By-Laws more expressive of their duties under present conditions. It is to be particularly noted that the Treasurer is to become a full-time member of the Institute staff. Also the office of Executive Vice President is established, the incumbent acting as a general manager of Institute affairs under the President, duties heretofore entrusted to the Secretary. It is the intention for the present to combine the offices of Executive Vice President and Secretary, but the duties of the two offices are laid down so that they may be separated in the future if it becomes desirable.

The duties of officers not specified in the By-Laws are determined by the Board of Managers as permitted under present By-Laws.

The sections of the By-Laws regarding committees are revised to provide more flexibility in the number of members in each committee, and to express more clearly the duties of the committees, particularly the Finance Committee.

The present By-Laws can be found on page 163 of the February 1947 issue of the JOURNAL.

Very respectfully,

RICHARD T. NALLE,
President.

As Approved by the Board of Managers, June 18, 1947.

ARTICLE I.

Stock.

Section 1. Omit "officers and" in line 6, second paragraph.

ARTICLE IV.

Management.

Section 1. The Institute shall be governed by a board of twenty-four (24) Managers elected by the members.

Section 2. The officers, who shall be elected by the Board of Managers, shall be a President, an Executive Vice President, not more than five Vice Presidents, a Secretary, an Assistant Secretary, a Treasurer, and an Assistant Treasurer. The Board of Managers may elect such other officers as it deems necessary.

Section 3. At the annual meeting of the Institute, eight Managers shall be elected each year to serve for three years, provided that the Managers now elected, or who may hereafter be elected, shall continue to serve until their successors be appointed.

Section 4. Present Section 3 (letter ballots, no proxies).

Section 5. Present Section 4, Nominations, omitting "President, Vice Presidents, Treasurer, and" in lines 2 and 3.

Section 6. Present Section 5, counting of votes, omitting "officers and" in 2nd from last line.

Section 7. Present Section 6 changed to read as follows: At the organization meeting of the Board of Managers, the Board of Managers shall elect the officers provided for in Section 2 of ARTICLE IV to serve for one year; and may at said organization meeting or from time to time thereafter elect such other officers as it may determine upon, etc., etc. (Present Section 6.)

Section 8. Present Section 7, Vacancies.

ARTICLE V.

Board of Managers.

Section 1. Change second sentence to read: The President, the Executive Vice President, the Vice Presidents, the Secretary, the Treasurer, the Chairman of the Committee on Science and the Arts, and the Chairman of the Library Committee shall be ex-officio members.

Sections 2, 3, 4, 5, 6, and 7 as at present.

ARTICLE VI.

Duties of Officers.

Section 1. Duties of the President, as at present except change to read ". . . shall be ex-officio a member of all standing committees of the Institute" in the last two lines.

Section 2. The Executive Vice President, under the supervision of the President, shall have immediate charge of all affairs of the Institute other than those matters specifically delegated by action of the Board of Managers pursuant to these By-Laws to the Executive Committee and the Finance Committee. He shall prepare the annual budget, and submit it to the Board of Managers for approval. He shall be an ex-officio member of all standing Committess of the Institute. He shall report to the President. In case of the disability of the Executive Vice President, the President shall designate another officer or other officers to assume his duties.

Section 3. In the absence of the President, the Executive Vice President shall exercise his duties. In the absence of both the President and the Executive Vice President, the Vice Presidents shall exercise the duties of President in order of their seniority in office.

Section 4. The Secretary shall be responsible for keeping the minutes of all meetings of the Institute and of the Board of Managers, shall keep the records of the Institute, and shall perform all the duties usually pertaining to the office of Secretary. He shall report to the Executive Vice President. In the absence or disability of the Secretary, the Assistant Secretary shall perform his duties.

Section 5. The Treasurer shall have custody of all monies received from the committee on Finance together with all monies received by the Institute from dues, admissions, and other operations of the Institute, depositing them, in the name of the Institute, in such bank or banks as the Board of Managers shall direct and disbursing them by checks signed as the Board of Managers shall likewise direct. He shall keep accounts of the receipts and disbursements and shall report thereon to the Board of Managers as directed. He shall have general supervision of the accounts of the Institute and shall render such financial statements as directed by the Board of Managers. He shall give bond to an amount and with such surety as the Board of Managers shall determine. The Treasurer shall report to the Executive Vice President. In

the absence of the Treasurer, the Assistant Treasurers shall, in the order of their seniority in office, perform his duties.

Omit all other present sections of this ARTICLE VI, viz. present Sections 4, 6, 7, and 8.

ARTICLE VII.

Unchanged.

ARTICLE VIII.

Committees of the Institute

Section 1. Add: 11. Committee on Research. Change No. 9 "Memorial and Museum Committee" to "Museum and Memorial Committee."

Section 2. Each standing committee of the Institute shall consist of the number of members determined on by the Board of Managers and composed of members of the Board of Managers and or non-members as may be desirable, except that the Committee on Science and the Arts shall consist of not less than sixty nor more than seventy-five members, and except that the Bartol Research Foundation shall consist of not less than ten nor more than fifteen members as provided for in Section 7 of this ARTICLE.

Section 3. Unchanged.

Section 4. Change "but twenty-two" in lines 7 and 8 to: "but one-third of the total number of."

Section 5. Unchanged.

Section 6. Each Committee shall report monthly to the Board of Managers through its Chairman. A copy of their report shall be in the hand of the Executive Vice President one week before the monthly meeting of the Board.

Section 7. Change "twelve" in line 2 to: "not less than ten nor more than fifteen."

Sections 7, 9, 10, 12, 13, 14, 15, and 16. Substitute "Executive Vice President" for "Secretary" in the places where it occurs.

Section 11. The Finance Committee shall have the custody and control of all the securities and investments of the Institute with full power and authority to buy and to sell, and to invest and reinvest the same; including the power to satisfy mortgages and extinguish ground rents, and to direct the placing of all such insurances on Real Estate held for investment as it may deem necessary, and to make such improvements, repairs and alterations to such Real Estate as it may deem necessary. It shall have power to authorize the proper officers of the Institute to execute the necessary papers to effect all purchases, sales and assignments of property other than real estate; to transfer registered securities; to subscribe to bond-holders' agreements to plans of reorganization involving any securities held by the Institute or in which it has an interest; and to do all such acts as are necessary in pursuance of the foregoing powers. It may, with the approval of the Board of Managers, appoint a Trust Company of the City of Philadelphia to act as Fiscal Agent under the direction of the Committee.

The Finance Committee shall keep a record of all its acts and proceedings, which shall be communicated to the Board of Managers.

Section 12. The Library Committee, in collaboration with the Executive Vice President, shall be of counsel and advice in the purchase of books and publications suitable to and consonant with the purposes of the Library; and in other matters pertaining to the Library.

Section 16. The Publications Committee, in collaboration with the Executive Vice President, shall be of counsel and advice with regard to all publications of the Institute other than publications of the Bartol Research Foundation.

Section 17. The Committee on Research shall, in collaboration with the Executive Vice President, be of counsel and advice to all research activities of the Institute except those of the Bartol and Biochemical Foundations.

Section 18. Old Section 17 re-numbered.

ARTICLE IX.

Meetings.

Section 1. Change 8:30 P.M. to 8:15 P.M.

LIBRARY NOTES.

The Committee on Library desires to add to the collections any technical works that members would wish to contribute. Contributions will be gretefully acknowledged and placed in the library. Duplicates received will be transferred to other libraries as gifts of the donor.

Photostat Service. Photostat prints of any material in the collections can be supplied on request. Orders received in the morning are filled the same day. The average cost for a print 9 × 14 inches is thirty-five cents.

The Library and reading room are open on Mondays, Tuesdays, Fridays and Saturdays from 9 A.M. until 5 P.M., Wednesdays and Thursdays from 2 P.M. until 10 P.M.

RECENT ADDITIONS.

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NOTES FROM THE BIOCHEMICAL RESEARCH FOUNDATION.

Explosion of a Rotor in an Analytical Air-driven Ultracentrifuge.—EDWARD B. SANIGAR AND JOHN H. HAMBLETON. The rotor which exploded was an analytical head magnetically supported and driven by an air turbine. The design of the rotor was essentially that published by Bauer and Pickels (1), although some modifications, detailed later, had been necessary during its fabrication. It had the usual solution cell and reference (or balancing) cell, and was intended for the optical observation of protein sedimentation in centrifugal fields.

THE ROTOR.

As will be seen from Fig. 1 the rotor (N) closely resembled the standard Pickels form, but differed from it by being larger, and by having flat portions where the cell holes were situated. The increase in size of the rotor over the Pickels model was necessitated by the diameter (4.375 in.) of the solenoid (A) used for the magnetic lift. This required, for an unobstructed passage of light through the solution cell (0), that the centers of the cells be placed 76.2 mm. (3.00 in.) from the axis of rotation, compared with 65 mm. (2.56 in.) in the Pickels rotor. Comparison values for the two rotors are given below.

Measurement	Pickels Rotor		B. R. F. Rotor	
	mm.	*in.*	*mm.*	*in.*
Maximum diameter	185	7.28	203.2	8.00
Minimum diameter	170	6.69	177.8	7.00
Distance from axis of rotation to center of cell hole	65	2.56	76.2	3.00
Over-all height of rotor including the two stems	135	5.32	135.6	5.34
Peripheral centrifugal force at 60,000 r.p.m.	372,300 × g.		408,900 × g.	
Centrifugal force at center of cell at 60,000 r.p.m.	261,600 × g.		341,500 × g.	

The rotor was made by Mr. C. H. Ludwig in our own machine shop from a "hand-forged and processed" aluminum alloy (14 S.T.) billet, approximately 9 in. in diameter by 5-3/8 in. thick, purchased from the Aluminum Company of America.

After the rotor had been shaped it was balanced with the cells in place before being used. The finished rotor weighed 8 lbs. 7-1/2 ozs. and with cells (0 and 0′) and top and bottom chucks (M and M′) weighed 9 lbs. 1-1/2 ozs.

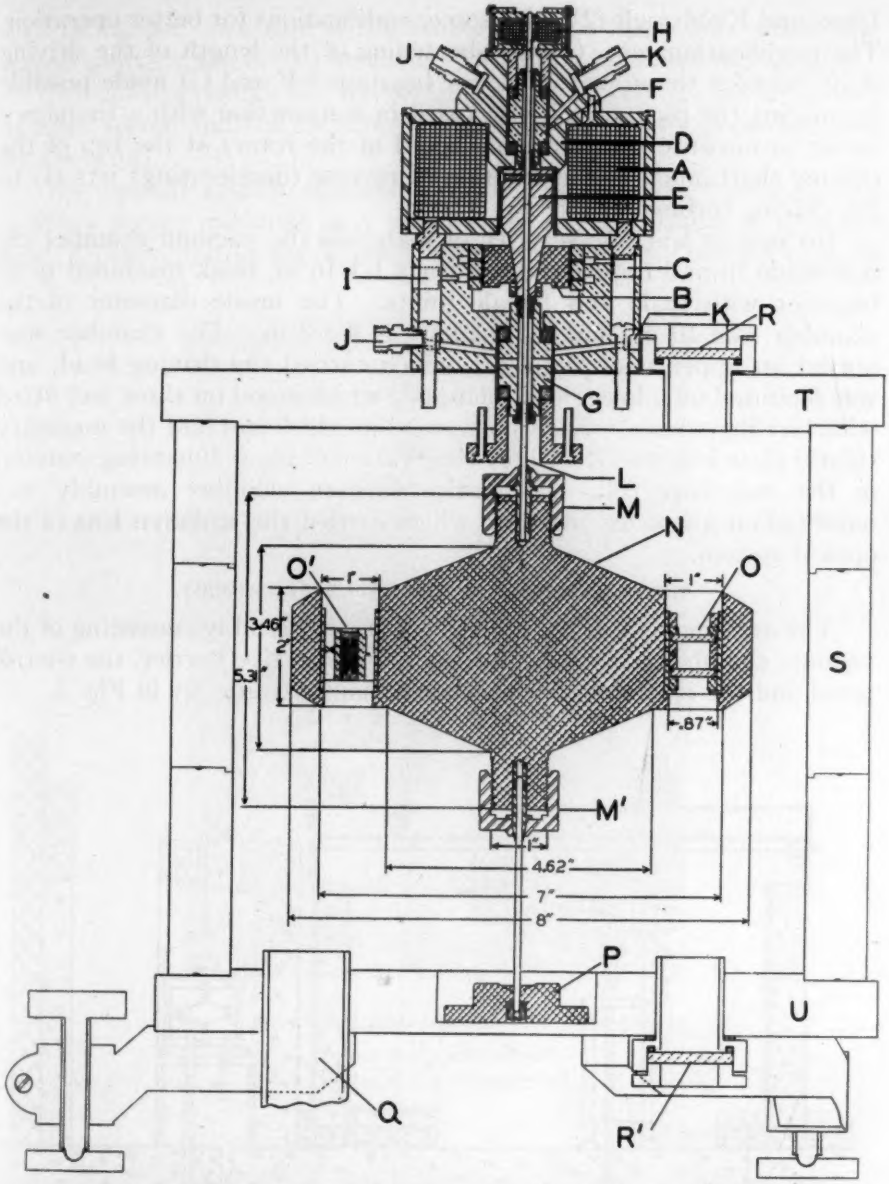

FIG. 1. Diagram of magnetically supported, air-driven ultracentrifuge.

THE MAGNETIC LIFT AND VACUUM CHAMBER.

In addition to the shape and dimensions of the rotor, the driving head with the magnetic lift used to support the centrifuge during operation, as well as the vacuum chamber in which the rotor spun, is shown in Fig. 1. The magnetic lift is based on the one described by

Dietz and Kishbaugh (2), with some modifications for better operation. The modifications are: (1) the shortening of the length of the driving shaft between the upper and lower bearings (F and G) made possible by placing the pick-up coil (H) (used in conjunction with a frequency meter to measure the rotational speed of the rotor) at the top of the driving shaft, and (2) the addition of reverse (decelerating) jets (I) to the driving turbine (B).

Because of wartime scarcity of materials the vacuum chamber (S) was made from 3 hot-rolled steel rings 1-1/16 in. thick machined to fit together with male and female joints. The inside diameter of the chamber was 10 in. and its height was 9-3/8 in. The chamber supported an upper steel plate (T), which carried the driving head, and was mounted on a lower steel plate (U) which stood on three feet fitted with leveling screws. Each plate was 1 in. thick and had the necessary (plate) glass window (R, R′) for observation of the sedimenting material in the centrifuge cell. The entire vacuum chamber assembly was mounted on a wooden platform which carried the schlieren lens of the optical system.

THE ARRANGEMENT OF THE CENTRIFUGE ASSEMBLY.

The arrangement of the entire centrifuge assembly consisting of the vacuum chamber and rotor, the concrete protective barrier, the control panel and the optical system, is shown diagrammatically in Fig. 2.

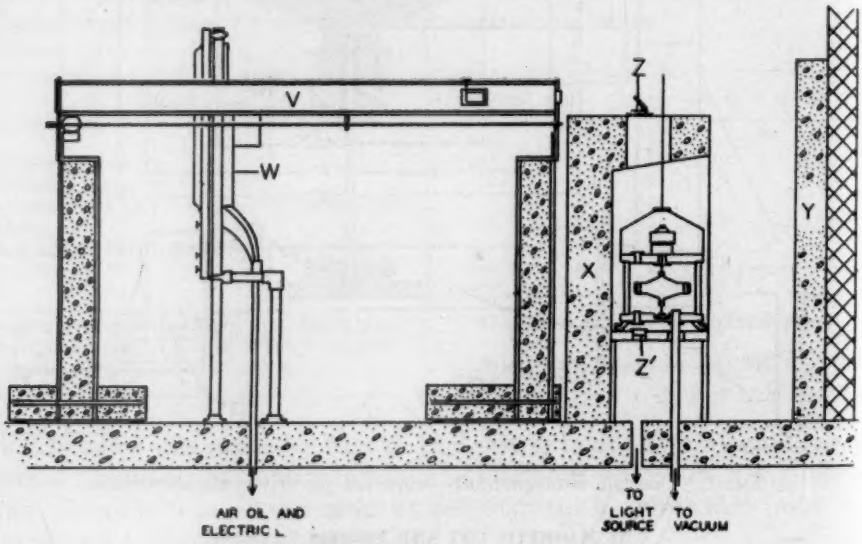

FIG. 2. Diagram of ultracentrifuge assembly.

The 8-in. thick reinforced concrete protective barrier (X) is one of the four centrifuge bays built into the centrifuge laboratory when the Biochemical Research Foundation building was erected. The room

wall facing the open side of the centrifuge bays has a 6-in. thick reinforced concrete shield (Y) for added protection as shown in Fig. 2.

The control panel (W), having automatic as well as manual control of rotor speed, and the air supply system, have already been described by Dietz (3).

The optical system consists of a General Electric Company H-4 mercury lamp, mounted in a pit beneath the centrifuge, a schlieren lens (Z′) mounted in the wooden base supporting the bottom plate of

FIG. 3. Rotor fragments collected after the explosion:

a. pieces of the solution cell.
b. pieces of the reference cell.
c. upper chuck.
d. lower chuck. (About one-fifth actual size.)

the centrifuge casing, and a front surface mirror (Z), mounted above an observation hole in the concrete barrier above the centrifuge, to reflect the light into the horizontal camera tube. The camera tube (V) is approximately 108 in. long with a 36 in. focal length lens, giving a 2:1 magnification on the photographic plate of the cell in the rotor. The necessary apparatus is available for taking photographs during a run by either the Longsworth scanning method or the Philpot-Svensson method.

THE EXPLOSION.

When the rotor exploded it had been accelerating for almost 35 minutes under a driving-air pressure of about 58 lbs. per square inch, manually controlled. At the time of the explosion it was accelerating at a rate of approximately 1,500 r.p.m./min., and had reached a speed of 58,800 r.p.m. (a reading of 980 c.p.s. on the frequency meter mounted in the control panel). The instruments on the control panel, as well as the sounds associated with the running of the machine, indicated that all parts were functioning properly; nevertheless, the rotor suddenly exploded without any prior indication of trouble.

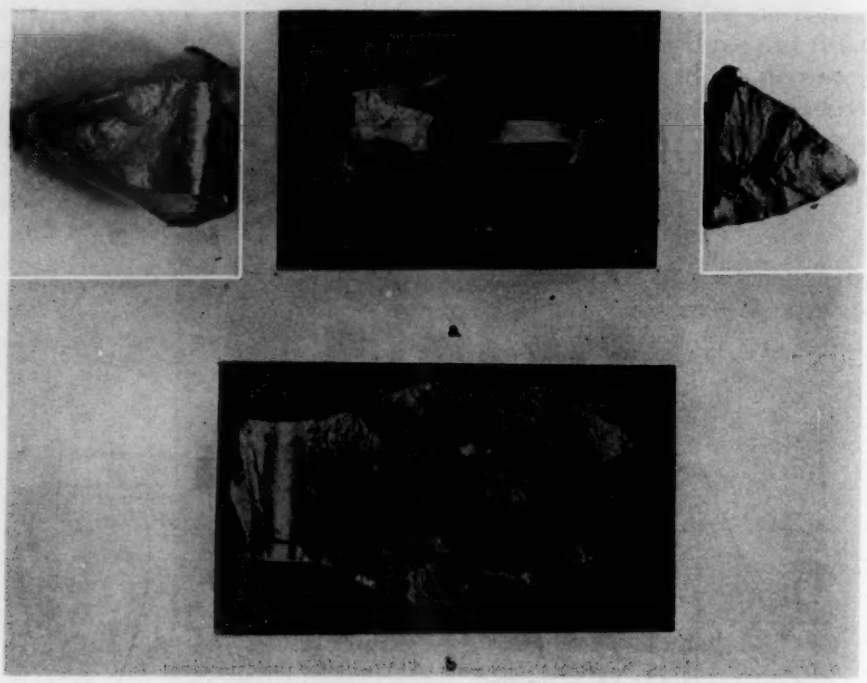

FIG. 4. Rotor fragments after the explosion. (About one-fourth actual size.)

Over a period of a month prior to the date of the explosion several runs at speeds up to 51,900 r.p.m. for periods up to 20 minutes had been made with this rotor. Careful measurement of the rotor dimensions after it had been run for 16 minutes at 51,900 r.p.m. failed to show any stretching or deformation.

While damage within the concrete barrier was extensive, and the inside surfaces of the concrete were chipped, there were no personal injuries, and damage to apparatus outside the barrier was negligible. Only very small fragments of the rotor ricochetted over the concrete barricade within which the explosion occurred. The large steel control

panel gave additional protection to the operators as shown by the fact that a number of small pieces of rotor were found on the floor at the rear of the panel, i.e., at the side of the panel nearest the centrifuge. These pieces must have had very little force since the back of the panel was not scarred by any impacts. Many of the pieces of rotor were hot when picked up very shortly after the explosion.

The collected fragments of the rotor are shown in Figs. 3 and 4. In Fig. 3 fragments recognizable as belonging to the solution cell are shown at "a", those belonging to the reference cell at "b", while at "c" and at

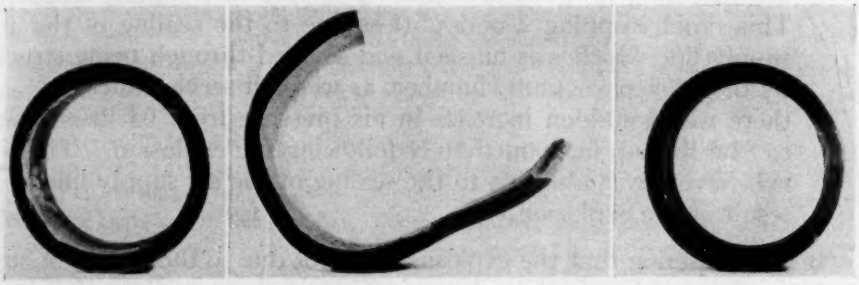

FIG. 5. The vacuum chamber after the explosion.

"d" are shown the portions of the rotor retained by the steel caps of the upper and lower chucks, respectively. Some of the fractured surfaces are shown in Fig. 4: the shape of the rotor along its minor axis is also shown by Fig. 4a, and that along the major axis by Fig. 4b.

CONCLUSIONS FROM COLLECTED FRAGMENTS AND FROM OPERATION CHARTS.

Examination of the fragments collected following the explosion (see Figs. 3 and 4) showed:

1. the rotor fractured along its major axis,
2. the fracture apparently started at the center of the rotor and not at the cell holes (note the conical shapes of the pieces of rotor still retained by the steel caps (see Fig. 3, "c" and "d")),
3. the center ring (3-1/2 in. high and 1-1/16 in. thick) of the three-section vacuum chamber caught the full force of the explosion and was blown apart, while the top and bottom rings (though blown to the floor) still retained their circular shape (see Fig. 5),
4. the drive shaft was sheared off about 1/2 in. below the lower bearing,
5. the section of the driving shaft remaining in the drive-unit still spun freely when rotated by hand afterwards, and the driving mechanism and magnetic lift were undamaged by the explosion,
6. the top plate and bottom plate of the vacuum chamber were only superficially damaged and could be used again,

7. the schlieren lens was undamaged, and the surface of the mirror was only lightly pitted over a small area, although both the lens and mirror were dislodged by the explosion.

Examination of the two recorder charts from the control panel revealed:

1. the rotor had attained a speed of 58,800 r.p.m. when the explosion occurred,
2. the turbine, relieved of the weight of the rotor, increased instantaneously in speed to 59,500 r.p.m. and then rapidly stopped. This rapid stopping was doubtless due to the sealing of the air supply line which was mashed and severed through being struck by the broken vacuum chamber, as were all service lines,
3. there was a sudden increase in air pressure from 63 lbs./sq. in. to 84.5 lbs./sq. in. immediately following the explosion. This, it is believed, was also due to the sealing of the air supply line as a result of the explosion.

It is our opinion that the explosion was not due to the failure of any of the equipment involved in the operation of the centrifuge, but was due to the disintegration of the rotor under too great a centrifugal force.

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(3) DIETZ, T. J., *J. Franklin Inst.* **236**: 451 (1943).

BOOK REVIEWS.

DIRECTORY OF LIBRARIES AND INFORMATIONAL SOURCES IN PHILADELPHIA AND VICINITY. 7th edition. Edited by Mrs. Catharine C. Grady for the Special Libraries Council of Philadelphia and Vicinity. 130 pages, 13 × 19 cms. Philadelphia, The Council, 1947.

A new edition of a standard work is always a welcome occurrence and this seventh edition of a directory of libraries in the Philadelphia area is no less so. The material contained in this directory will serve several uses. It gives in the alphabetical list the location of a particular library and hours when it is open. Further data are the conditions under which the library may be used and what facilities it has for making its material available by reproduction, photostat or microfilm.

However, the greatest value of the directory is for those seeking information on the subject resources of Philadelphia libraries. Each entry includes information on the major subjects covered in the library's collection and any special collections it may own. A subject index provides a ready key to this material. For example forty-three libraries are listed under the heading chemistry and others under chemical engineering, chemicals, chemistry-medical and pharmaceutical, and chemistry, physical. More specialized subjects such as catalysis, sugar, jet propulsion engines, linoleum might be mentioned as indicative of the range of technical interest of Philadelphia libraries.

A personnel index includes the names of the leading staff members of the libraries listed, in addition to serving as a membership list of the Special Libraries Council of Philadelphia and Vicinity.

P.

ELEMENTS OF MECHANISM, by Peter Schwamb, Allyne L. Merrill and Walter H. James; sixth edition revised by Venton Levy Doughtie. 428 pages, illustrations, 15 × 24 cms. New York, John Wiley and Sons, Inc. 1947. Price $4.00.

The science of mechanism is divided into two parts: (1) Pure mechanism or geometry of machinery which treats of the motion and forms of the parts of a machine and the manner of supporting and guiding them, independent of their strength, and (2) Constructive mechanism which involves the calculation of the forces acting on diffrent parts of the machine, and the selection of materials as to strength, durability and other physical properties in order to withstand these forces. This text is intended to give familiarity with the application of the fundamental principles of Kinematics in the field of mechanical movements and therefore refers to the first part of the science of mechanism.

This is the sixth edition of the book, the first having been brought out in 1885. It incorporates revisions, rewriting, new illustrative examples and new problems for exercise. The student is introduced to the work by a series of definitions following which motion and vectors are discussed. The methods for obtaining velocities are then described, emphasizing coplanar motion, and involving resolution and composition, instantaneous axis of velocity, centro, and relative velocity or velocity polygon. This precedes acceleration analysis, developing the relative acceleration method. Subsequent chapters deal with linkages which describe the four bar linkage used in mechanism analysis and the transmission of motion by direct contact where the bodies constituting the driver and follower are in pure rolling contact or sliding between surfaces in connection with friction drives, gears, cams and screws. A later chapter is devoted to belts, ropes and chains, and finally a treatment is given to miscellaneous mechanisms such as hoisting tackle, parallel motion by cords, inclined plane and wedge, screws and screw threads. and the ratchet wheel.

The author believes in exercise to impress the subject matter. There are many problems at the end of chapters. In the back there are laboratory problems that may be worked on 18 × 24 in. paper. Problems are stated in words, no sketches provided, and are arranged according to subject headings. The average time required to work each problem is given. A subject index completes the work. The book provides a rigorous treatment using both graphical and algebraic methods, and employing the simpler methods of calculus which may be omitted without destroying the continuity of the work.

R. H. OPPERMANN.

COLLEGE TECHNICAL PHYSICS, by Robert L. Weber, Marsh W. White and Kenneth V. Manning. First edition. 761 pages, illustrations, 16 × 23 cms. New York and London, Mc Graw-Hill Book Company, Inc., 1947. Price $4.50.

The science of physics which provides the tools for the chemist, geologist, engineer and astronomer has also originated the scientific method about which much is heard today. The principal aspects of the scientific method are selective analysis, accurate measurement and mathematical treatment. Fields of knowledge other than physics, by common consent, are considered scientific to just the extent that their ideas are subject to these aspects. The study of physics, to be inclusive of this recognized valuable element, must be thorough from the very fundamentals and adapted to the prerequisites of the student. Clarity and complete understanding in each of the aspects are necessary. The authors of this book bring forth in the preface that its purpose is to help in the acquisition of basic physical principles and to apply them in the solution of technical problems by the scientific method. It is suited to college level students.

The general topics covered in order are mechanics, heat, sound, electricity and magnetism, and light. A considerable portion is devoted to the first of these much of which is required in orienting the student to the new situation including a description of the fields and uses of physics, and vectorial representation. Near the end of this and in preparation for the study of heat, an exposition of the molecular theory of matter is given. The treatment on heat itself has a short coverage in a number of pages, but examination reveals it is one of the best presented in the book, especially with its illustrations and application of formulas to solve pertinent problems. The following subject of sound is to some extent in this class also. Magnetism and electricity covers the largest part of the book and includes electrical instruments and measurements, chemical effects of electric current, induction, capacitance, alternating currents and electronics. The last subject, light, covers reflection, refraction, color, optical instruments, diffraction, and polarized light. A final chapter entitled "Twentieth Century Physics" selects certain important additions to our knowledge since the year 1895 and explains their application to devices and techniques that have brought forth improved contributions to current civilization and revolutionized warfare.

The presentation is a logical sequence of well connected topics. The restriction of the use of mathematics to algebra and trigonometry brings the usefulness of the book within a much broader circle, even though the coverage of the contents is restricted in proportion. The outstanding feature of the book is clarity coupled with a continued inspiration. A serious minded student should be able to follow the text, to solve the illustrative problems, and work out answers to the questions and problems at the end of chapters with a minimum of outside help. The preparatory paragraphs in each chapter, the photographs of outstanding physicists with brief references to their contributions at the beginning of chapters, and such chapters as the Use of Physics and Twentieth Century Physics furnish color to the study.

R. H. OPPERMANN.

TOWARD BETTER PHOTOGRAPHY, by Vincent McGarrett. 260 pages, illustrations, 14 × 20 cms. Boston, American Photographic Publishing Co., 1947. Price $3.00.

The author presents this book with suggestions for the photographer in all types of photography. Throughout the work many ideas are given to correct errors and improve methods

for making better photographs. The book is comprised of seventeen chapters covering lighting, darkroom work, different types of printing, color and color photography and finally a chapter on camera clubs and exhibitions.

Photography has always been an interesting subject and, although many books have been written in this field, a book such as this one is a welcome addition for both the amateur and professional photographer.

P.

RUSSIAN–ENGLISH TECHNICAL AND CHEMICAL DICTIONARY, by Ludmilla Ignatiev Callaham. 794 pages, 14 × 20 cms. New York, John Wiley & Sons, Inc., 1947. Price $10.00.

For those needing a dictionary of Russian technical terms this should prove a useful work. Including some 60,000 words and phrases, it is broad in scope and covers a wide range of subject fields. Its strength lies in chemistry and the various allied process industries such as plastics, synthetic rubber, petroleum and food. It also covers extensively mineralogy, metallurgy, general engineering, mechanics, electrical engineering, pharmacy and botany. Among the subjects more selectively covered are aeronautics, radio, meteorology, agriculture, medicine, physics and mathematics. This dictionary is not limited to technical terms but includes general terms, which might be found in technical literature, to an extent sufficient to free the user of the necessity of constantly referring to a general Russian-English dictionary. Older words have been included in addition to the modern Soviet terminology.

The author has introduced several useful features which should be noticed. The subject field of many words is indicated such as "(geol.) (zool.)." Clarifying phrases have been included in many definitions and the Latin names of botanical and zoological words are given to make identification certain. The inclusion of many phrases involving proper names and the abbreviations of the names of various Russian organizations and government departments are noteworthy.

The introduction offers several pertinent comments on the procedures used in compiling the dictionary which should be familiar to any regular user. To facilitate translation of words not included in the dictionary there is added a list of Russian technical word endings with English equivalents and examples in both languages.

The printing is clear and easily legible. In total, a valuable addition to Russian-English dictionaries and one which might well be owned by any indivicual or library working with Russian technical literature.

GEO. E. PETTENGILL.

PUBLICATIONS RECEIVED.

Yarn and Cloth Calculations, by Lloyd H. Jackson. First Edition. 1926 pages, drawings, 13 × 22 cms. New York, Textile Book Publishers, Inc., 1947. Price $6.00 U. S. and Canada, $7.00 in foreign countries.

College Physics, by John A. Eldridge. Third Edition. 720 pages, drawings and illustrations, 14 × 22 cms. New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Limited, 1947. Price $4.50.

Materials of Industry, by Samuel Foster Mersereau. Fourth edition revised. 623 pages, drawings and illustrations, 15 × 21 cms. New York and London, McGraw-Hill Book Company, Inc., 1947. Price $2.80.

Elementary Fluid Mechanics, by John K. Vennard. Second Edition. 339 pages, drawings, 14 × 22 cms. New York: John Wiley & Sons, Inc., London: Chapman & Hall, Limited, 1947. Price $4.00.

Manual of Foundry and Pattern Shop Practice, by Otis J. Benedict, Jr. First Edition. 361 pages, drawings and illustrations, 12 × 19 cms. New York and London, McGraw-Hill Book Company, Inc., 1947. Price $3.25.

Air Conditioning and Elements of Refrigeration, by Samuel P. Brown. First Edition. 644 pages, drawings and illustrations, 15 × 23 cms. New York and London, McGraw-Hill Book Co., Inc., 1947. Price $6.00.

Television, edited by Alfred N. Goldsmith, Arthur F. Van Dyck, Robert S. Burnap, Edw. T. Dickey, George M. K. Baker. Vol. III, 1938–1941. 486 pages, drawings and illustrations, 15 × 23 cms. New Jersey, Radio Corporation of America, 1947. Price $2.50; Cloth bound edition $1.50.

Television, edited by Alfred N. Goldsmith, Arthur F. Van Dyck, Robert S. Burnap, Edw. T. Dickey, George M. K. Baker. Volume IV, 1942–1946. 510 pages, drawings and illustrations, 15 × 23 cms. New Jersey, Radio Corporation of America, 1947. Price $2.50, Cloth bound edition $1.50.

Characterisation of Organic Compounds, by F. Wild. 306 pages, tables, 14 × 22 cms. Cambridge University Press, 1947. Price $3.75.

Elements of Electrical Engineering, by Arthur L. Cook, Clifford C. Carr. Fifth edition. 662 pages, drawings and illustrations, 15 × 24 cms. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd. 1947. Price $5.00.

Heat Pumps, by Philip Sporn, E. R. Ambrose and Theodore Baumeister. 188 pages, drawings and illustrations, 14 × 22 cms. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1947. Price $3.75.

Physics, for Students of science and Engineering, by William H. Michener. 646 pages, drawings, 14 × 22 cms. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1947. Price $4.25.

Mathematics as a Culture Clue and Other Essays, by Cassius Jackson Keyser. 277 pages, portraits, 14 × 21 cms. New York, Scripta Mathematica, 1947. Price $3.75.

Bibliography of the Platinum Metals 1918–1930, by James Lewis Howe and Staff of Baker & Co., Inc. 138 pages, 19 × 29 cms. Newark, N. J., 1947. Price $5.00.

The Water-Soluble Gums, by C. L. Mantell. 279 pages, drawings, 16 × 24 cms. New York, Reinhold Publishing Corporation, 1947. Price $6.00.

Men and Volts at War, The Story of General Electric in World War II, by John Anderson Miller 272 pages, illustrations, 15 × 24 cms. New York, Whittlesey House 1947. Price $3.75.

An Introduction to Crystallography, by F. C. Phillips. 300 pages, 500 diagrams, 14 × 22 cms. New York, Longmans, Green & Co., Inc., 1947. Price $6.50.

CURRENT TOPICS.

Teleran Developed as Air Navigation Aid. (*Electrical Engineering*, Vol. 66, No. 2.)—Details of teleran, an aid to safe navigation which evolved from wartime radar developments, recently were revealed by the Radio Corporation of America in connection with the first public test of the system at the Indianapolis Airport.

Teleran, derived from the words, "television–radar air navigation," provides in pictorial form all the information a pilot needs in the air. It does this irrespective of visibility, and is believed to have a range of 30 to 50 miles. It is presented as the solution to all problems of air navigation, traffic control, collision prevention, and instrument flight.

By this newly developed system, a ground radar unit scans the sky and ground area of the airport and collects information which is delineated on radar scopes in the form of the familiar radar pattern. One indicator is used for each altitude layer. What the radar reports is collated at the ground station from time to time or continuously as requirements may dictate. Television cameras are trained on the radars, and the whole is transmitted as a motion picture to a screen mounted on the airplane's instrument panel. The pilot need only glance from time to time at the television receiver screen to see the whole picture of his surroundings: other nearby airplanes; the runways on the field; all towers, buildings, and other obstructions; direction of flight; and other geographical and meteorological data; as well as traffic control directions from the ground control officer in charge. He sees also his own airplane in flight and its position with respect to other airplanes and the earth. Signals received from each airplane over the field are separated electrically from each other and sent out as a composite elevation signal.

Development of the system now is being carried on largely under contract with the Army Air Forces. Loren F. Jones of the R.C.A. engineering products department was responsible for the basic idea of the system, and Doctors Douglas Ewing, Vladmir K. Zworykin (F'45), Irving Wolff, and P.J. Herbst were associated with its development.

R. H. O.

Electrical Insulation.—Electrical insulation, originally a problem of the engineer and physicist, has now been handed to the chemist and must be solved if electrical progress is to continue, F. M. Clark, General Electric insulation expert, told audiences on his recent tour of several southern cities.

"Truly it is an orphan that must be adopted," Mr. Clark said. "The synthesis of insulations, custom-designed for the chemist's investigations, offers a profitable field for exploitation."

Mr. Clark pointed out that electrical development and application have reached the point where better insulation is necessary so that development will not be slowed. Many insulations in use today, he said, were among the first developed.

The insulation expert, twice winner of the Charles A. Coffin Foundation Award for outstanding achievement, one of which was the development of askarel, the noninflammable dielectric sold as Pyranol and used as a transformer and capacitor filler, is the holder of almost a hundred patents of which a majority are in the field of insulation.

Mr. Clark also asserted that chemical reactivity and chemical stability are related to the same fundamental factors which determine dielectric stability and suitability.

"New and improved insulations are needed to provide the backbone of electrical insulation in high voltage apparatus," Mr. Clark told the members of the six A.C.S. chapters which heard his talk. "The answer is only to be found in the chemist's awakening to the opportunities before him—to the realization that as a representative of a major energy-consuming industry there lies before him an energy-producing industry which, freed from the limitations imposed by the use of traditional 'pipe lines' of insulation, will not only offer him a fertile field for the exploitation of his products but will in its own progress offer him tools now undreamed of for the efficient promotion of chemical reactions and synthesis of the future."

R. H. O.

Yale University-General Electric Joint Research on Guided Missile Controls.—To permit ground testing of guided missile controls, a flight simulator or dummy rocket for duplicating flight characteristics of a rocket missile is under development as part of General Electric's long-range rocket research program, according to announcement by Ray Stearns, manager of the company's Aeronautics and Marine Engineering Division.

The simulator will couple an intricate calculating machine with a mechanical arrangement of gymbals driven by devices known as servomechanisms. When completed, the guiding equipment to be used in any new type of rocket can be attached and tested in the same maneuvers through which the rocket will be directed when actually launched.

In addition, research on controls for the simulator is being conducted by the Dunham Laboratory of Electrical Engineering at Yale University in conjunction with the G-E program, Mr. Stearns said.

The project at Yale, under the direction of John L. Bower, Assistant Professor of Electrical Engineering, will be complicated by the fact that the necessarily compact design of a rocket missile and the tremendous forces acting upon it in flight which may amount to millions of horsepower, require controls which are exceedingly rapid in their response. This, in turn, makes necessary even higher performances in the testing equipment. The characteristically complex motion of the missile when travelling at supersonic velocities has made it essential to improvise and develop new devices for making the desired determinations.

The research will be concentrated on testing the complicated control devices which keep guided missiles on their course by manipulating the vanes that direct the flow of escaping jet gases from the missile in its flight.

Construction of a dummy rocket will allow engineers to reproduce the rolling and pitching of a real rocket as it responds to its control vanes in flight.

The test device will permit great economies in rocket development and production, eliminating the need for expensive test shots. It is estimated that each of these trial launchings cost several hundred thousand dollars.

This research will permit observations and adjustments of the control devices during conditions corresponding to flight and will aid in perfecting the design of missile controls. In addition, the techniques under investigation will permit a final check on each missile before the actual launching, thus preventing misfires.

R. H. O.

Schuylkill River Tunnel to Use High Pressure Gas-Filled Pipe Cable.—High-pressure gas-filled pipe cable and accessories for three 69-kv. circuits and ten 13.2-kv. circuits, featuring positive stop joints for sectionalizing gas pressures, and special handling devices, will be installed in the Schuylkill River Tunnel by the Philadelphia Electric Company.

Two of the high-voltage, high-pressure gas-filled cables will replace existing overhead tower crossings on the Schuylkill to Chester and the Schuylkill to Paschall transmission lines. They will consist of 700,000-cm. conductors with .315 inch of mass impregnated paper insulation and aluminum backed strand shielding, copper shielding and D-shaped skid wires. The pressure medium will be specially purified dry nitrogen at 200 psi. pressure. These lines will be rated 55,000 kva.

The third transmission circuit will be part of the Philadelphia Electric program for a loop of large capacity transmission cables between the strategic points of their system. This circuit will be a section of the 100,000-kva. line between Schuylkill and Westmoreland. The conductor size will be 2,000,000-cm. segmental. All the accessories will be made interchangeable to simplify maintenance and stocking of parts. This line will use positive stop joints for sectionalizing gas pressures approximately every mile.

The ten 13.2-kv. circuits will consist of three single conductor 500,000 cm. cables insulated with .250 inch of no. 1799 varnished cambric applied by special methods for vertical riser service. The three lead-covered cables will be twisted together in the factory and will then be installed in one length from special reels equipped with brakes and handling ropes. These circuits, rated 8000 kva. each, will handle Pennsylvania Railroad and general distribution loads.

The tunnel now being built to accommodate the cable circuits will have an eight-foot bore. It will drop vertically for 120 feet at one end and 90 feet at the other end. The horizontal section of the tunnel will be 1030 feet long. The 69-kv. circuits will be placed in steel trays and the 13.2-kv. circuits will be racked in Transite trays.

Forced ventilation will be required to dissipate the losses and prevent mutual heating between circuits. This will be accomplished by placing a blower in the shaft house at one end.

R. H. O.

Castings Made Leakproof for Pressure Service. (*Compressed Air Magazine*, Vol. 52, No. 2.)—Microporosity such as usually characterizes magnesium-alloy castings apparently does not affect their usefulness for the general run of

applications, but where they are subjected to internal air, gas, or liquid pressure of 2 to 3 atmospheres they must be leakproof. Castings of this kind for airplane turbosuperchargers, gas turbines and jet-propulsion engines, oil manifolds, compressor casings, etc., are usually tested before service at pressures up to 50 percent. more than the operating pressures for which they are designed. Heretofore, when areas were found to be pervious, the parts had to be rejected as inadequate; but now, because of improved sealing solutions and methods of impregnation, the defect can be remedied.

The choice of solutions is wide and includes both organic and inorganic materials; and the processes lend themselves to small-scale or continuous large-scale production. A set-up of the latter kind includes a storage tank with cooling coils to keep the fluid at a temperature below 70° F., an autoclave or impregnator to hold the castings, a vacuum pump to evacuate the autoclave, and a source of compressed air to force the solution into the castings.

Vacuum of 27 inches Hg (mercury) or better is applied for 20 minutes to withdraw the air from the impregnator and the pores in the castings. At the end of that period the vacuum is released, the solution is allowed to enter, and air at from 70 to 90 pounds pressure is admitted. This is maintained at from 30 to 60 minutes, depending upon the wall thickness of the castings. Then follows draining, rinsing to remove any excess solution from the surfaces, and heating of the castings for two hours in a closed furnace at a temperature of 275° F. to polymerize the solution in the pores. In cases of exceptional porosity, two impregnations may be required.

Where individual castings are to be treated, the steps before and after impregnation are the same as just described. But after evacuation, all except one of the openings in a casting are plugged, the latter is filled with the solution, and the opening is closed with a cap through which air at from 70 to 90 pounds pressure is introduced and held for at least fifteen minutes, or until the fluid oozes slowly out of the pores. Inasmuch as it has so far not been possible entirely to eliminate microporosity in magnesium-alloy castings, the method of sealing with the aid of vacuum and compressed air will prevent scrapping castings for pressure service that otherwise are physically sound.

R. H. O.